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# Appendix 2 - Effectiveness Monitoring Report: Evaluating Snowshoe Hare Use of Northeastern Washington Forest Types 1997-2002

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## 1. Introduction

The objective of effectiveness monitoring is to determine whether applying the guidance contained in the Lynx Habitat Management Plan results in anticipated habitat conditions. Effectiveness monitoring of the 1996 Lynx Plan consisted of two major components: 1) sampling to verify the suitability of forest stands as Forage Habitat and Denning Habitat, and 2) sampling to assess snowshoe hare use of forest stands. Results of the effectiveness monitoring conducted from 1996 through 2002 are presented below. Results of the snowshoe hare pellet study were applied to develop a new definition of lynx Forage habitat.

For land managers operating in the range of snowshoe hare, understanding distribution of snowshoe hare in forested habitats is a first step in managing habitat for forest carnivores, especially lynx. The category of “lynx forage habitat”, habitat that supports high densities of snowshoe hare, plays a key role in DNR’s Lynx Plan. A study designed to evaluate snowshoe hare habitat use within lynx habitat range was conducted as part of the effectiveness monitoring of the 1996 Lynx plan. This is a first step in the effort to expand our understanding of where snowshoe hare occur along a forest successional gradient, and it will enable the DNR to make more educated decisions about lynx habitat management.

Objectives and summary of the snowshoe hare habitat relationship study are presented in Sections 2 and 3 below. A detailed description of the study design, statistical methods, the data analyses results, and discussion are presented in Sections 4 through 6. The process of developing a new lynx forage habitat definition and discussion of the definition are presented in Section 7 of this Appendix.

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## 2. Objectives

This study had two main objectives:

1. To expand the knowledge on snowshoe hare habitat use in forests of northeastern Washington, and
2. To develop a new definition of lynx forage habitat based on information about snowshoe hare habitat use

The working hypotheses were:

1. Hare pellet densities would be higher in Loomis State Forest than in the Little Pend Oreille block,
2. Forest stages with dense cover (young stands as well as older stands with understory) would have more pellets than stages with low cover, and
3. Pellet densities would differ by ecosystem type or plant association favoring lodgepole pine.

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## 3. Summary

To evaluate snowshoe hare habitat use on DNR-managed lands within lynx range, a pellet study was conducted. Habitat occupancy by snowshoe hares was indexed by the number of fecal pellets per habitat. The number of pellets is known to be related to the abundance of snowshoe hares (Litvaitis et al. 1985a, Krebs et al. 1987, Krebs et al. 2001, Murray et al. 2002).

### 3.1 STUDY AREA AND METHODS

Hare pellets were sampled in different forest types and successional stages in two landscapes - Loomis State Forest (Loomis) and Little Pend Oreille Block (LPO). A total of 58 stands were sampled in Loomis and 32 stands were sampled in LPO. Sampling in the Loomis State Forest (LSF) and Little Pend Oreille block (LPO) was originally stratified according to ecosystem type and age class from existing forest inventories. Three ecosystem types were recognized for each study area: wet subalpine fir, dry subalpine fir, and Douglas fir for Loomis; and western hemlock, red cedar, and grand fir for LPO. Disturbance histories of the sites ranged from unmanaged to sites harvested within the last 30 years.

Within each surveyed stand, ten pellet plots were installed along a “U” shaped permanent transect 810 feet (270 m) long. Pellets were initially removed from the plots in the fall when transects were established. Pellets were then counted and removed in the spring and fall of each sample year, except in 2002, when pellets were counted in fall only. Detections of the lynx alternative prey (grouse and squirrels) as well as deer and cattle were noted at any location along the transects.

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The physical characteristics of the site recorded at each transect were slope, aspect and elevation. The species of vegetation browsed by hares (woody stems, needles, and forbs) within 3 feet (1 m) of the 12-inch (0.3 m) pellet plot was recorded in categories reflecting quantity of browse marks.

Standard forest structure measurements were also taken at four stations per transect, including tree height, diameter, tree densities by species and size class, snag height and diameter, etc. At each pellet plot (10 per transect), vegetation was sampled in three cover categories: 1) overhead (canopy), 2) ground, and 3) horizontal cover.

### **3.2 KEY FINDINGS OF THE HABITAT USE ANALYSES**

1. Pellet densities in LPO ranged from 3.1 pellets/m<sup>2</sup> (in year 2000) to 4.7 pellets/m<sup>2</sup> (in 1999 and 2001). In Loomis the lowest density was 4.8 pellets/m<sup>2</sup> (in 1997) and the highest was 15.9 pellets/m<sup>2</sup> (in 1998). Translated into hare abundance these data result in 0.173-0.348 hares/ha on LPO and 0.3-0.7 hares/ha on Loomis (mean of all transects over all years studied). A minimum of 0.5 hares/ha is thought to be necessary to sustain lynx in northwestern Canada (Ruggiero et al. 2000).
2. Both the highest and lowest values of hare densities observed on Loomis and LPO are lower compared to northern hare populations where lynx have been studied, but similar to those reported from other southern areas.
3. The ten sites with highest pellet densities reflected what sites were available on the landscape. These were Douglas fir, lodgepole pine, Engelmann spruce, and subalpine fir dominated stands.
4. Horizontal cover between 3-6 feet (1-2 m) was the most highly correlated habitat characteristics to mean pellet abundance on both study areas.
5. No clear stand age-pellet relationships were seen on LPO, the study area with available age data.
6. Sites with many pellets had more cover by shrubs and moss, more medium trees (1-5.5 inches dbh) and fewer large snags (>5.5 inches dbh).
7. Tree species significantly correlated with hare pellet abundance on LPO were grand fir, western red cedar, and western hemlock. Negative correlations were observed between pellets and larger lodgepole pine (5-15 inches dbh). On Loomis, pellet abundance correlated negatively with larger Engelmann spruce (5-15 inches dbh) and Douglas fir (25-30 inches dbh).
8. Multivariate analyses identified potential habitat variables, which can explain approximately 20 percent more variation in pellet densities than our best a priori model.
9. The average observations of browsed shrubs exceeded conifers and overall browsed items were more diverse in LPO, where shrubs were broadly distributed. Shrubs and conifers were browsed similarly on Loomis.
10. Alternative lynx prey was well distributed on sites occupied by hares, from sites with few to many pellets. The presence of red squirrels and grouse were related to

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the abundance of pellets on LPO but not Loomis. Ungulates were also well distributed on the sites, suggesting opportunities for browse competition.

11. Cattle presence was more common on Loomis than LPO; was negatively correlated with pellet abundance on Loomis; and was more frequent on sites with few rather than many pellets.
12. Multivariate analyses did not identify a relationship between a stand canopy multistory and hare pellet abundance.

### **3.3 DEVELOPMENT OF A NEW LYNX FORAGE HABITAT DEFINITION**

1. The results of this study suggest that the definition of Forage Habitat used in the 1996 Lynx Plan (WADNR 1996a) was based upon sound habitat relationships.
2. However, the definition was inadequate in at least two ways. First, some types of older stands contribute to hare habitat and therefore should be eventually included as Forage Habitat. Second, the threshold value of 40 percent horizontal cover was too low, allowing many low-density hare sites to be included in the forage habitat category.
3. A revised forage habitat definition could be based on horizontal cover scores. The success in accurately classifying forage habitat using this variable was 87.5 percent for Loomis and 90.5 percent for LPO.
4. Forage habitat is defined through horizontal cover above average snow level. The stand qualifies as forage habitat when it has no more than four zero scores (no cover) measured in 40 readings (four readings taken at each of the 10 sampling points on a transect within 1.5-2.0 m range of a vegetation profile board viewed from 45 feet (15 m) from the four cardinal directions.
5. The definition was based on relatively small samples on LPO
6. An additional variable, density of grand fir, was necessary to minimize the error when using the definition on LPO.
7. When applying the new forage habitat definition to both areas, DNR can anticipate the highest misclassification error in older stands.

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## **4. Methods**

### **4.1 STUDY AREA**

This study was conducted on two blocks of land managed by the Washington Department of Natural Resources that have been delineated as lynx habitat (WDW 1993, Stinson 2001).

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- The larger block of habitat (32,167 ha), in the higher elevations of the Loomis State Forest (1220–2500 m), occurs within the Thompson Okanogan Highlands Ecoprovince. On the eastern edge of the Cascade mountains, the Loomis study area includes two major forest zones: Douglas-fir (PSME) and subalpine fir (ABLA) (Williams and Lillybridge 1983). Many of the subalpine fir sites are currently occupied by lodgepole pine (PICO). Engelmann spruce (PIEN) and western larch (LAOC) are also common. Lynx were studied on parts of the Loomis study area in the mid-1980's (Brittall et al. 1989, Koehler 1990b) and reproducing lynx continue to be tracked there (M. Skatrud, pers. comm.).
  - The second and smaller (6,145 ha) study area, the Little Pend Oreille Block (LPO), occurs in the mixed conifer zone of Shining Mountains Ecoprovince (Ruggiero et al. 1994). Mixed conifer forests of the LPO contain 10 primary coniferous species with western red cedar (THPL), western hemlock (TSHE), and grand fir (ABGR) plant associations being the most common (Williams et al. 1995). Elevations range from approximately 1000 m to just over 1350 m. The last lynx sighting in the area was in 1996 (Stinson 2001). Since then one animal was videotaped there in the summer of 2004 (USFWS videotape).

Sampling on the Loomis and LPO was originally stratified according to ecosystem type and age class from existing forest inventories. Three ecosystem types were recognized for each study area: wet subalpine fir, dry subalpine fir, and Douglas-fir for Loomis and western hemlock, western red cedar, and grand fir for LPO. Major plant associations within each type are listed in Table A2.1. (for an explanation of the abbreviations see Appendix 4) After field verification, sampled sites were regrouped according to the dominant species (Table A2.2) within the three size classes of tree data (large tree (>5.5 inches dbh), medium tree (1-5.5 inches dbh), and seedling (<1 inch dbh)). On LPO, four groups were identified: ABGR, THPL, PICO and PSME. On Loomis, the groups were ABLA, PICO, PIEN, and PSME. Two age class stratifications were selected to ensure that relatively infrequently occurring young stands were sampled. “Recently disturbed stands” included those that had harvest activity within the past 30 years. “Older stands” included all other forested management units. The type of disturbance, such as regeneration harvest versus commercial thinning, was not considered in this classification. At both study areas, final stand selection was constrained by accessibility, as parts of each study area remain unroaded.

**Table A2.1**  
**Major plant associations occurring within each ecosystem type by study area \***

<b>Loomis State Forest</b>		
<b>Wet Subalpine Fir</b>	<b>Dry Subalpine Fir</b>	<b>Douglas-fir</b>
ABLA2/RHAL ABLA2/LIBOL ABLA2/VACCI PIEN/EQUIS	ABLA2/CARU ABLA2/VASC-CARU ABLA2/VASC	PSME/ARUV PSME/VACCI PSME/CARU PSME-PIPO/AGIN PSME/SYAL
<b>Little Pend Oreille Block</b>		
<b>Grand Fir</b>	<b>Western Hemlock</b>	<b>Red Cedar</b>
ABLA/VASC ABGR/LIBO	TSHE/CLUN ABLA/VASC	THPL/CLUN THPL/ATFI PSME/PHMA

\* For an explanation of plant association abbreviations see Appendix 4.

## 4.2 FIELD METHODS

### Pellet counts

Snowshoe hare habitat occupancy was indexed by the number of fecal pellets per habitat. The number of pellets is related to the abundance of snowshoe hares (Litvaitis et al. 1985a, Krebs et al. 1987, Krebs et al. 2001, Murray et al. 2002). Although this relationship has not been specifically confirmed in our study area, the broad success of pellet count methods for estimating relative abundance of hares and rabbits (Ångerbjörn 1983, Wood 1988) suggests that the technique is robust and appropriate for the indirect interpretation of habitat occupancy patterns at the scale of this study.

**Table A2.2**  
**Sampled stands on Loomis State Forest and Little Pend Oreille Block grouped by dominant tree species and disturbance regime**

Age Classes	LOOMIS STATE FOREST				LITTLE PEND OREILLE BLOCK				Total
	ABLA	PICO	PIEN	PSME	ABGR	PICO	PSME	THPL	
<b>Recently Disturbed</b>	1	9	2	13	4	4	6	6	45
<b>Older</b>	4	7	11	11	3	3	4	2	45
<b>Total</b>	5	16	13	24	7	7	10	8	90

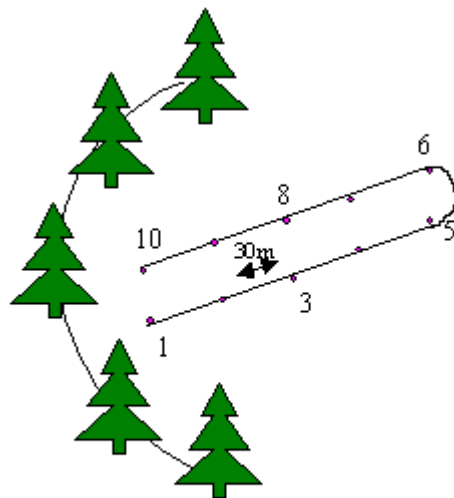
Within each surveyed stand, ten pellet plots were installed along an 810-foot (270 m) “U” shaped transect (Fig. A2.1a). Transects started approximately 120-foot (40 m) from the

edge of each stand in the most homogenous region identified from an aerial photograph or orthophoto. Long, narrow pellet plots 2 inches x 10 feet (5 cm x 300 cm), also known as Krebs plots (Krebs et al. 1987, Krebs et al. 2001), were established every 90 feet (30 m) with random orientation. To improve the probability of encountering pellets in the suspected low-density study areas, pellets were also counted in larger 12 inches x 10 feet (30 cm x 300 cm) plots that centered on and overlapped the Krebs's plots (Fig. 1b). Pellets were initially cleared off the plots in the fall of transect establishment. Pellets were then counted and removed in spring and fall of each sample year, except in 2002, when pellets were counted only in the fall.

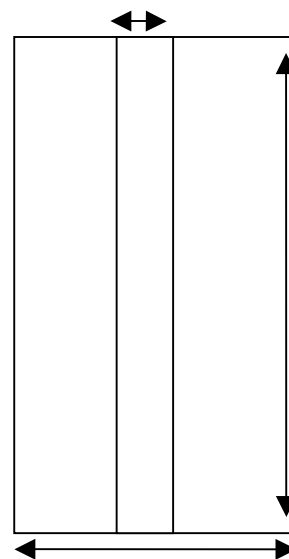
### Figure A2.1. Sampling design

a) layout of pellet transect within stand, b) pellet plot design

a) transect layout: 10 stations



b) pellet plot design at each station



The number of transects in each study area increased over the course of the study. Pellet transects were first installed in Loomis in 1997. Most of the stands (n=23 out of 29) were selected randomly. However, six were selected for their potential to be occupied by snowshoe hares to ensure that quality habitat would be represented in the data. Other random transects were installed over the next five years to gradually increase the sample size. Additionally, some transects were lost due to timber harvest. These were replaced in adjacent stands after harvest, resulting in 58 transects for Loomis by 2002. Within LPO, 30 transects were installed in 1998 and two were added in 2000. All sampled stands in both study areas were within a 20-minute walk from the nearest drivable road.

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## **Physical Site Characteristics**

At the first station of each transect, the slope, aspect and elevation were noted. The slope position was categorized as rolling, extreme concavity, shallow concavity, shallow convexity, extreme convexity, straight surface, or rolling/complex. Extreme convexity was only observed once in each study area and was lumped with shallow convexity for analysis.

## **Vegetation Sampling**

At each pellet plot (10 per transect), vegetation was sampled in three cover categories: 1) overhead (canopy), 2) ground, and 3) horizontal cover. A vertical sighting tube (James and Shugart 1970, Noon 1981) was used to describe overhead and ground cover at 12 points per station, every 15 feet (5 m) from station center to 45 feet (15 m) in the four cardinal directions. Four categories of overhead cover were possible: open (no cover), conifer, broadleaf, or western larch. Seven categories of ground cover were recognized: grass/forb (including low shrubs), litter, moss, rock, soil, shrub (tall shrubs), and conifer. Horizontal cover was estimated using a 6-foot by 1-foot (2 m x 30.5 cm) cover board viewed at 45 feet (15 m) from four cardinal directions (Nudds 1977). Horizontal cover was scored at 50cm height intervals from ground level to 6 feet (2 m). Scores were measured on an ordinal scale ranging from 0 (no cover) to 5, representing 20 percent cover by each numerical category.

Standard forest structure measurements were also taken at four stations per transect (stations 2, 4, 7 and 9 on Fig. A2.1), including tree densities by species and size class in fixed (1/100 acre or 40.5 m<sup>2</sup>) and variable plots. Seedlings were tallied by species on the fixed plot and heights were measured on a subset (first two of each species encountered as the observer turned clockwise starting from north). Medium trees (1-5.5 inches dbh, 2.5 - 14 cm) were tallied by diameter class and species on the fixed plots. Large trees and snags (>5.5 inches dbh, 14cm) were tallied on the variable radius plots. Diameters of all large trees and snags were measured, and tree height, height to live crown, and crown radius were measured on a subset of the medium and large tallied trees (first two trees of each species encountered as the observer turned clockwise starting from north).

## **Snowshoe Hare Browse**

The species of vegetation browsed by hares (woody stems, needles, and forbs) within 3 feet (1 m) of the larger 12 inches (0.3 m) pellet plot was recorded in three categories that reflect the quantity of browse marks: few (1-5 observed marks), some (6-10), or many (>10). Hare browse was recognized as those with 45-degree angle cuts and observers were instructed to only record data for those marks that they could confidently conclude as derived from hares. Data was averaged over years collected (1999 to 2001) for analysis. The percent of browse marks observed was weighted by the quantity of marks observed: few (no weight), some (marks multiplied by 3), many (marks multiplied by 5).

## **Presence of Alternate Prey and Browse Competitors**

Signs of grouse, squirrel, deer, and cattle presence within pellet plots were noted. Grouse and deer signs (absent, old, or new pellets) were recorded when they occurred within 3 feet (1 m) of the larger pellet plot (12 inches). Signs of squirrels included chewed cones, pellets, and middens (holes in piles of cone bracts/seeds). Signs of cattle included presence of animals, cow pies, or tracks. Detections of deer, cattle, grouse, and squirrels were noted at any location along the transects. For analysis, the mean number of pellet plots with detections was averaged over the years data was collected per transect (cow, grouse and squirrel 1999-2002; ungulate 1999-2001).

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## 4.3 DATA ANALYSIS

### Estimation of Hare Density

Snowshoe hare pellet counts from spring and fall were summed to give an annual total. Mean counts per transect (stand) per year were calculated, excluding initial plot-clearing counts, and log-transformed to normalize the data. Hare densities were also calculated from mean hare pellet counts in the 2"x10' Krebs' plots using the EXCEL spreadsheet described in Krebs et al. (2001), for comparison to other areas. Counts from the larger (12"x10') plots and hare densities were highly correlated (Pearson's  $r=0.96$ ), such that a minimum hare density suggested for lynx (0.5 hares/ha, Ruggiero et al. 2000) is represented by just under 10 pellets per 12"x10' plot. However, hare density results must be reviewed with caution because the computation was developed for hare densities in the Yukon: the equation may not be assumed accurate in low-density areas like Washington (Murray et al. 2002). For this reason, and because pellet data from the 12"x10' plots were closer to being normally distributed than hare densities, data from the 12"x10' plots were used for habitat analyses.

### Estimation of Yearly Dynamics in Pellet Density

Yearly dynamics of hare pellet density were analyzed on a subset of transects that had been counted each year for the longest time possible. On Loomis, 21 transects were monitored in 1997-2002 and on LPO, 30 transects were monitored in 1998-2002. Mean hare pellet counts from the 12"x10' plots per transect/stand are used in the analyses and expressed as pellets/m<sup>2</sup> for each year studied to facilitate comparison to other study areas that may have used different plot sizes. The 12"x10' plot is similar in terms of area (1 foot or 0.93m<sup>2</sup>) to a 1 m<sup>2</sup> circular plot used and/or advocated in other studies (Koehler 1990a, Murray et al. 2002). Repeated measures ANOVA was employed for both pellet abundance (per m<sup>2</sup> per transect) and pellet presence (percentage plots with pellets per transect) because pellets were counted on the same sites every year.

### Analyses of Snowshoe Hare Habitat Relationships

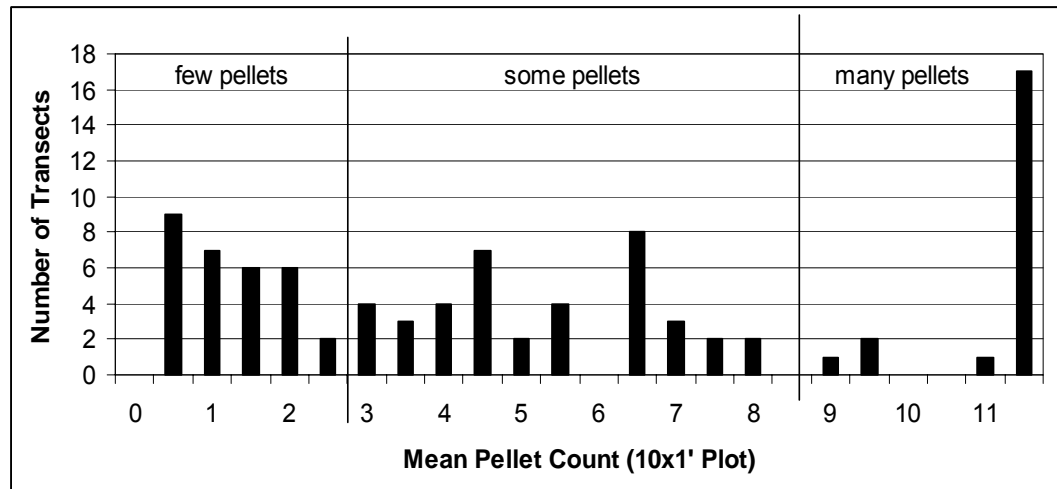
Habitat variables were either log-transformed (count data) or arc-sin transformed (percentage cover data, using equation 14.5 from Zar (1984). Analyses of hare habitat occupancy began with ANOVAs (pellet category, study area). Individual correlations were then calculated for comparison to hare habitat relationships reported in the literature or for specific questions of management interest. For example, uncorrected Spearman rank correlations of pellet density with conifer densities and heights were provided to give managers as much detail as possible about the occurrence of pellets in structurally different forests. Influence of the physical site characteristics on pellet densities was analyzed with Pearson correlations (pellets with slope, elevation), Mann-Whitney U tests (study area comparisons of slope, elevation), ANOVAs (pellets between slope configuration categories), and Raleigh's test (aspect).

Univariate analyses of pellet counts from the 12"x10' plots were used to identify key habitat variables and to provide detailed information to land managers. The count data was either log-transformed or grouped into three abundance categories, following observed breaks in the data while maintaining reasonably similar sample sizes in each category (Figure A2.2): few (<2.5 mean pellets/plot), some (2.5-7 pellets/plot), or many (>8 pellets/plot). The categories will help managers differentiate good from poor sites relative to what occurs on local sites, enabling them to select the best forage habitats available for meeting the landscape level forage

habitat guidelines of the Lynx Plan. All sites categorized as having few pellets had less than 0.12 hares per hectare and 3 out of 21 sites categorized as having many pellets had at least 0.5 hares per ha.

**Figure A2.2. Number of transects with a given mean pellet count, for both study areas, used to derive pellet categories**

n=30 few, n=39 some, n=21 many



After redundant habitat variables (Spearman's  $r^2 \geq 70\%$ ) were removed from the dataset, multivariate models for predicting pellet densities on the 12"x10' plots were developed in two steps. First, models based on the literature were developed. Second, step-wise regression procedures were used to develop an alternative set of candidate models. Residual plots and scatterplots were examined for meeting model assumptions (i.e. normality, colinearity) and for the presence of outliers ( $>4$  SE). Akaike's Information Criteria (corrected for small sample size) were calculated to evaluate the a priori models (Burnham and Anderson 1998). The multivariate modeling procedures were repeated for 2"x10' Krebs' plots for comparison.

Analyses were performed with SPSS Systat software program (Wilkinson 1997). Probabilities were reported for correlations and pairwise comparisons in ANOVA, and correlations were adjusted by the Bonferroni method, unless otherwise noted. For parametric statistics, count variables were log transformed and percent variables were transformed with arcsine (Zar 1984). The program ORIANA was used to analyze the distribution of pellets on sites according to aspect (Raleigh's test).

## 5. Results

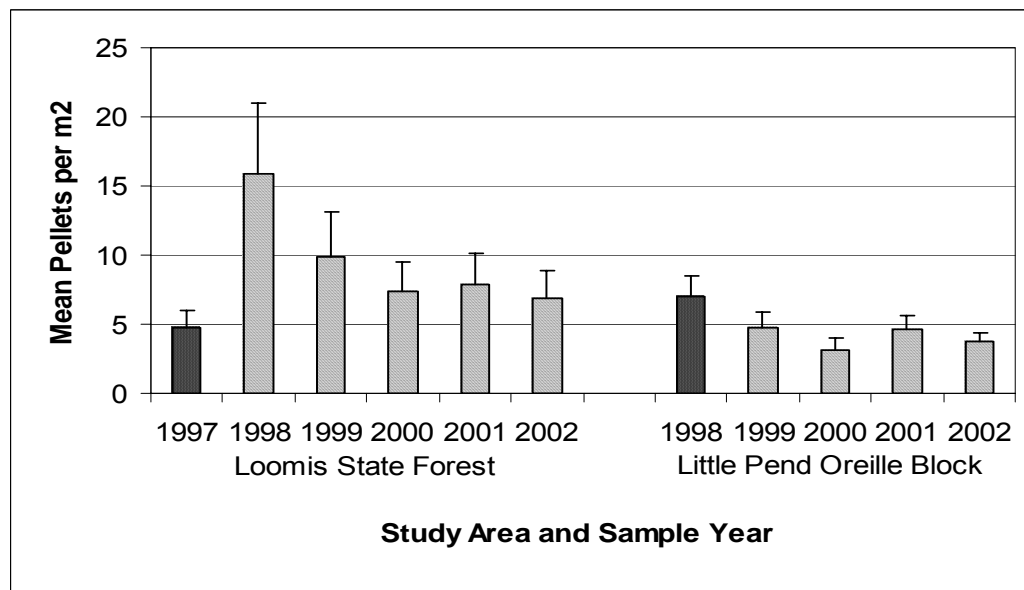
### 5.1 HARE PELLET PRESENCE AND ABUNDANCE THROUGH TIME

Between 1997 and 2002, fluctuations in pellet densities on the study areas were of low amplitude (Figure A2.3). On Loomis (n=21), fluctuations in pellet densities showed higher amplitude in differences between years than LPO. The year of transect initiation (1997) should have been the highest year of pellet counts, but instead was the lowest

(mean=4.8 pellets/m<sup>2</sup>) - 3.3 times lower than the highest year of 1998 (15.9 pellets/m<sup>2</sup>). No individual transects had their highest counts in 1997, and none had their lowest counts in 1998. Presence of pellets on the plots followed a trend similar to abundance (Fig. 4), with 55 percent of the plots/transect having pellets in 1998. However, the lowest year (47.4 percent) was 2000 rather than 1997, and 2000 was the only year in which all transects had at least one pellet. Repeated ANOVA measures showed a largely quadratic change through time for the abundance of pellets/plot (df=5, F=6.143, p<0.0005) but no change for the presence of pellets/plot (df=5, F=0.849, p=0.518), with the increase from the 1997 to 1998 and the decrease from 1998 to 1999 significant in pellet abundance.

**Figure A2.3. Mean (std. error) pellets per square meter tallied in 12 inches x 10 feet plots at Loomis State Forest (n=21) and Little Pend Oreille Block (n=30)**

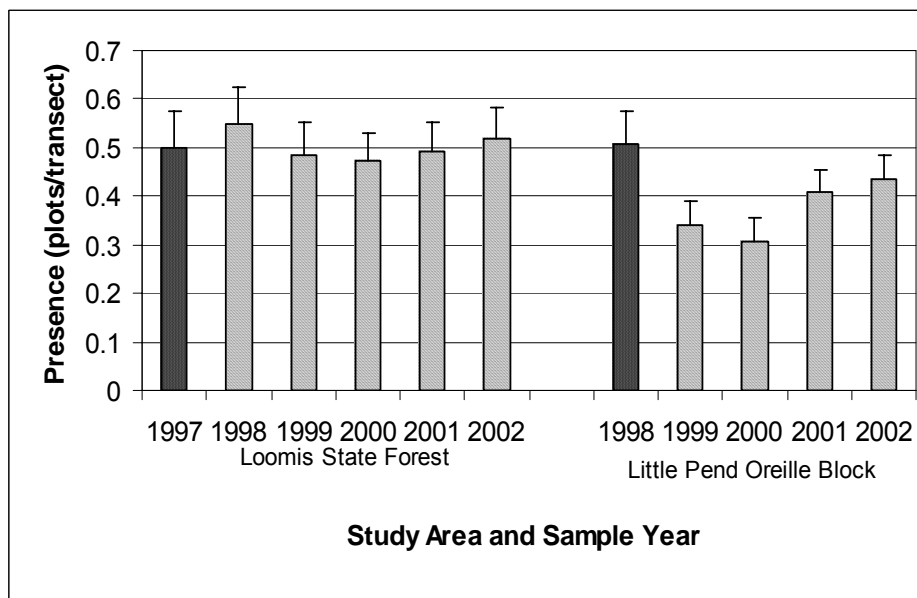
First bar in each time series represents the number of pellets present when transects were first established.



Between 1998 and 2002 on LPO (n=30), there was only a 1.5 fold difference between the lowest (2000, mean=3.1 pellets/m<sup>2</sup>) and highest year (1999, mean=4.7 pellets/m<sup>2</sup>, Fig. 3). On individual transects in 2000, mean pellet abundance was lowest at 15 sites and highest at one site. Presence of pellets within sites followed abundance (Fig. 4), with only 30 percent of plots per transect having pellets in 2000 compared to 44 percent in 2002. No pellets were found at any station on 6 out of 30 sites in 2000 compared to 1 out of 30 in 2001. Repeated ANOVA measures showed a largely quadratic change through time for both the abundance (df=4, F=2.882, p=0.026) and presence of pellets/plot (df=4, F=8.647, p<0.0005), with the increase from 2000 to 2001 significant in both cases and the decrease from 1999 to 2000 significant in pellet abundance. The decrease from 1998 to 1999 was expected given that the 1998 data represents initial counts (not time-standardized) compared to the annual accumulations represented by the other sampling years.

**Figure A2.4. Mean (std. error) pellet presence in 12 inches x 10 feet plots at Loomis (n=21) and LPO (n=30).**

First bar in each time series represents the number of pellets present when transects were first established.



Equations from Krebs et al. (2001) were used to estimate hare densities on Loomis and LPO from pellet densities within 2"x10' plots. Over the years studied, hare densities ranged from 0.29-0.69 hares/ha on the Loomis (n=21) and from 0.18-0.35 hares/ha on the LPO (n=30, excluding initial counts in 1997 for Loomis and 1998 for LPO).

## 5.2 PREDICTING HARE PELLET DENSITIES FROM HABITAT CHARACTERISTICS

Comparison of Akaike weights for regression analyses on mean pellet densities using habitat variables of interest (Table A2.3) suggests that 51 percent of the variation in pellets in the 12"x10' plots can be explained by five a priori variables (horizontal cover, study area, shrub cover, broadleaf canopy, number of trees with low height-to-live-crown;  $n=90$ ,  $F_{(5,84)}=19.34$ ,  $p<0.0005$ ). Stepwise multiple regression on the larger suite of habitat variables suggested that a model with 12 variables could explain 70 percent of the variation in pellet abundance: horizontal cover, study area, mean dbh of large trees, number of large (>5.5") spruce, number of pine seedlings (<1" dbh), number of subalpine fir seedlings, broadleaf canopy cover, number of large hemlock, ground cover of shrubs, ground cover of soil, mean height to live crown of large trees, and number of large subalpine fir (listed in order of t-value;  $n=90$ ,  $F_{(12,77)}=18.44$ ,  $p<0.0005$ ; Table A2.4).

**a) Horizontal cover** had the strongest relation to pellet densities. There was little pattern in the relation of cover to pellets by forest type (Fig. A2.5). Our a priori hypothesis that total tree density would be strongly related to pellets was also confirmed (Fig. A2.6), but tree density was not retained in the higher performing models. Loomis had higher pellet densities than LPO, and was apparent in most models as either "study area" or "elevation" (Fig. A2.7).

**b) Other cover variables** (including broadleaf canopy, and soil and shrub ground cover) were represented in the models, yet showed little significant correlation to

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pellets density. Broadleaf canopy occurred on 22 out of 32 LPO sites and 30 out of 58 Loomis sites (Fig. A2.8). However, conifer and open canopy cover categories were better able to discriminate good from poor sites in univariate analyses (Table A2.3). Soil cover was slightly more common on Loomis (38 out of 58) than LPO (17 out of 32) and was absent on many of the high density pellet transects. Shrub cover (Fig. A2.9) occurred on 31 percent of transects in both LPO and Loomis but was more strongly related to pellets on LPO ( $r=0.402$ ) than Loomis ( $r=0.089$ ). Forb/grass, litter and moss cover had stronger relationships to pellet densities than shrub or soil cover (Table A2.3).

**c) Characteristics of large trees** (>5.5 inches dbh) also contributed to prediction of pellet densities, including mean diameters, numbers of certain species, presence, and height to live crown. All but one stand had large trees (89 out of 90 stands). Generally, a negative relation of tree diameter to pellet density was seen (Fig. A2.10 and Fig. A2.11). Pellet densities were expected to be higher when the height to live crown of large trees was shorter, but the relationship in the data was not apparent (Fig. A2.12) and wasn't detected in univariate analyses (Table A2.4). Presence of large trees (number of plots with large trees), reflecting the patchiness of tree distribution in a stand, was related to pellets but driven by young sites with high pellet densities and few large trees.

**d) Tree species** also contributed to a prediction of pellet densities in the form of medium trees (1-5.5 inches dbh) and seedlings (<1 inch dbh, < 7 feet tall). Medium subalpine fir and grand fir (Fig. A2.16) with diameters of 1-5.5 inches were not significantly related to pellets but their occurrence differed by study area. In univariate analyses for LPO, medium grand fir and cedar were positively related to pellets and subalpine fir was negatively related to pellets. Pine seedlings showed a generally negative relation to pellets (Fig. A2.17) and subalpine fir, no relation to pellets (Fig. A2.18), but mean seedling height was related to pellets in univariate analyses (Table A2.4). The negative relationship between large Engelmann spruce (Fig. A2.13, Table A2.8) and pellets was not expected.

**Table A2.3**

**Two-way ANOVA results for Habitat structure variables between study areas (LSF= Loomis, LPO= Little Pend Oreille) and pellet categories (f=few, s=some, m=many).**

Post-hoc test results reported when  $p \leq 0.05$  ( $n=90$ ).

Variable	Study Area			Pellet Category			Interaction of Site and Pellet Category		
	F <sub>(1, 84)</sub>	p	post-hoc	F <sub>(2, 84)</sub>	p	post-hoc	F <sub>(2, 84)</sub>	p	post-hoc
<b>Ground Cover</b>									
grass/forb	0.53	0.47	----	9.98	<0.0005	m<f>s	4.70	0.012	LPO f > LPO s,m and LSF m,s,f
conifer	12.69	0.001	LPO>LSF	2.47	0.090	----	0.22	0.81	----
soil	3.96	0.050	LSF>LPO	1.53	0.22	----	2.49	0.089	----
litter	3.39	0.069	----	4.66	0.012	f<s	1.27	0.29	----
moss	3.02	0.086	----	4.01	0.022	f<m	0.85	0.43	----
rock	5.19	0.025	LSF>LPO	1.22	0.30	----	0.41	0.66	----
shrub	5.09	0.027	LPO>LSF	3.01	0.055	----	2.54	0.085	----
<b>Horizontal Cover</b>									
0-0.5m	17.59	<0.0005	LPO>LSF	0.76	0.49	----	0.16	0.85	----
0.5-1.0m	14.19	<0.0005	LPO>LSF	8.74	<0.0005	f<m	1.60	0.21	----
1.0-1.5m	5.23	0.025	LPO>LSF	12.37	<0.0005	f<m>s	1.26	0.29	----
1.5-2.0m	1.23	0.27	----	12.79	<0.0005	m>s>f	1.18	0.31	----
# Zeros 1.5-2 m	2.32	0.13	----	15.02	<0.0005	f>s>m	0.24	0.79	----
# Zeros 0-2.0m	9.94	0.002	LSF>LPO	15.88	<0.0005	f>s>m	0.52	0.60	----
<b>Overhead (Canopy) Cover</b>									
broadleaf	4.59	0.035	LPO>LSF	0.33	0.72	----	3.62	0.031	LPO m>LSF m
conifer	1.99	0.16	----	3.55	0.033	f<s	0.88	0.42	----
larch	5.67	0.019	LPO>LSF	1.27	0.29	----	1.17	0.32	----
open	4.36	0.040	LSF>LPO	2.46	0.091	----	1.30	0.28	----
conifer canopy + conifer ground	5.90	0.017	LPO>LSF	4.11	0.020	f<m	0.34	0.71	----
open canopy – conifer cover	15.53	<0.0005	LSF>LPO	5.03	0.009	f>m	0.10	0.90	----

**Table A2.4**

**Two-way ANOVA results for Forest characteristics (tree data) between study areas (LSF= Loomis, LPO= Little Pend Oreille) and pellet categories (f=few, s=some, m=many).**

Post-hoc test results reported when  $p \leq 0.05$  ( $n=90$ ).

Variable	Mean Pellet Category			Mean (SE)		
	F <sub>(2, 87)</sub>	p	post-hoc	Few (n=30)	Some (n=38)	Many (n=22)
<b>Seedlings (&lt;1" dbh)</b>						
Total # (# per plot)	0.493	0.612	-----	171.3 (32.6)	120.711 (20.417)	77.318 (13.358)
Mean height (inches)	3.158	0.047	m>s	2.438 (0.228)	1.877 (0.175)	2.716 (0.334)
Max height (inches)	2.275	0.09	-----	6.947 (0.448)	5.497 (0.449)	7.314 (0.869)
<b>Medium Trees (1-5.5" dbh)</b>						
Total # (# per plot)	13.737	<0.0005	m>f,s	9.200 (1.618)	15.605 (2.156)	55.091 (13.482)
Presence per plot (plots without trees)	3.090	0.051	m>f	0.367 (0.060)	0.263 (0.043)	0.170 (0.053)
Mean height (feet)	4.340	0.016	f<s	15.306 (1.429)	19.261 (1.103)	17.930 (1.131)
Height to live crown (feet)	1.569	0.214	-----	13.219 (5.362)	6.087 (0.849)	6.232 (1.133)
Crown radius (feet)	4.594	0.013	s>f	2.938 (0.243)	3.735 (0.198)	3.011 (0.188)
<b>Large Trees (&gt;5.5" dbh)</b>						
Total # (trees per acre)	4.779	0.011	s>m	135.183 (13.253)	224.772 (25.781)	137.870 (24.597)
Mean height to live crown (feet)	2.394	0.097	-----	24.370 (1.944)	26.048 (2.026)	20.286 (2.294)
Mean height (feet)	4.934	0.009	f>m<s	77.212 (3.187)	73.929 (2.937)	60.124 (4.860)
# 25' height intervals	4.831	0.010	f>m	3.633 (0.182)	3.184 (0.159)	2.727 (0.256)
Mean DBH (inches)	5.095	0.008	f>m<s	13.427 (0.733)	12.682 (0.665)	10.270 (0.915)
Maximum DBH (inches)	4.397	0.015	f>m	23.927 (1.376)	22.868 (1.657)	17.986 (1.902)
Crown radius (feet)	4.029	0.021	f>m	8.793 (0.434)	7.847 (0.418)	6.966 (0.630)
Presence per plot (plots without trees)	6.829	0.002	f>m<s	0.167 (0.069)	0.263 (0.090)	0.818 (0.224)
# Snags (trees per acre)	3.861	0.029	f>m<s	14.614 (2.666)	29.807 (7.770)	5.315 (1.743)

**Table A2.5**

**A set of candidate models (*a priori* above double line) for predicting pellet densities from habitat variables.**

Habitat Variables Modeled	Adj. R	K	RSS	AICc	$W^{**}$
study area, total medium (1-5.5") trees	0.280	4	9.19	-196.9	0
study area, total ( $\geq 1$ ") trees	0.312	4	8.77	-201.0	0
horizontal cover	0.388	3	7.89	-212.8	0
horizontal cover, study area	0.433	4	7.11	-220.0	0.020
horizontal cover, study area, shrub cover	0.451	5	6.13	-220.1	0.022
horizontal cover, study area, shrub cover, broadleaf canopy*	0.482	6	6.46	-224.1	0.15
horizontal cover, study area, shrub cover, broadleaf canopy, # trees with low height-to-live-crown	0.508	7	6.07	-227.4	0.80
horizontal cover, elevation, broadleaf canopy, large PIEN, moss cover	0.580	7	5.18		
horizontal cover, medium ABGR, medium ABLA, broadleaf canopy, forb/grass cover, large PIEN, pine seedlings, total trees, mean diameter large trees	0.652	11	4.09		
horizontal cover, study area, broadleaf canopy, large PIEN, TSHE seedlings, medium ABLA, medium ABGR, pine seedlings, large trees ( $>5.5$ " ), large tree presence	0.672	12	3.79		
horizontal cover, study area, broadleaf canopy, pine seedlings, mean dbh large trees, large PIEN, ABLA seedlings, large TSHE, shrub cover, soil cover	0.677	12	3.74		
horizontal cover, study area, broadleaf canopy, pine seedlings, mean dbh large trees, large PIEN, ABLA seedlings, large TSHE, shrub cover, soil cover, mean HLC large trees, large ABLA	0.702	14	3.37		
horizontal cover, elevation, large tree presence, broadleaf canopy, total PICO, total large trees, large TSHE, large PIEN, mean diameter large trees, moss cover, medium LAOC, medium ABLA, medium ABGR	0.716	15	3.16		

\*original hypothesis for canopy relation to pellets was conifer, but broadleaf proved to be a stronger canopy variable

\*\* probability that the model is the best-approximating model among those considered

**Table A2.6**

**Regression coefficients for predicting pellet density from habitat variables**

<b>A priori model</b>	$y (\log \text{ pellets}) = -0.463 - 0.655(\text{deciduous canopy}) + 1.472(\text{horizontal cover}) + 0.183(\text{study area}) + 0.939(\text{shrubs cover}) - 0.106(\# \text{ trees with low height-to-live-crown})$
<b>Multivariate model</b>	$y (\log \text{ pellets}) = 0.327 + 0.395(\text{study area}) - 0.110(\text{pine seedlings}) - 0.151(\text{large PIEN}) + 0.235(\text{large TSHE}) - 0.888(\text{mean DBH large trees}) + 1.271(\text{horizontal cover}) - 1.028(\text{soil cover}) + 1.106(\text{shrubs cover}) - 0.778(\text{broadleaf canopy}) - 0.173(\text{ABLA seed}) + 0.111(\text{large ABLA}) + 0.250(\text{mean HLC large trees})$

Other species that entered the multivariate model were western hemlock and subalpine fir. Only seven stands (LPO) had large western hemlock and these stands were likely to have generally higher pellet densities (Table A2.7). Large subalpine fir was present on 15 Loomis sites and 5 LPO sites and there was no clear trend with pellets (Figure A2.5; Tables A2.7 and A2.8). A positive relationship between lodgepole pine density and pellets was expected (Figure A2.5), but lodgepole pine did not play a significant role in the models.

**Table A2.7**

**Spearman rank correlations ( $r_s$ ) of conifer densities (#) and heights (ht) by size classes with pellet counts on LPO (n=32).**

seedlings <1"dbh, medium trees 1-5.5"dbh, large trees >5.5"dbh

	ABGR	ABLA	LAOC	PICO	PIEN	PIMO	PIPO	PSME	THPL	TSHE
# seedlings	0.038	-0.096	-0.017	-0.760 <sup>d</sup>	-0.176	-0.356 <sup>b</sup>	-0.126	-0.368 <sup>b</sup>	0.400 <sup>b</sup>	0.255
seed ht	0.070	-0.139	-0.047	-0.650 <sup>d</sup>	-0.140	-0.410 <sup>b</sup>	-0.126	-0.391 <sup>b</sup>	0.449 <sup>b</sup>	0.176
# med trees	0.351 <sup>b</sup>	-0.322 <sup>a</sup>	-0.007	-0.190	0.103	-----	-----	-0.104	0.529 <sup>c</sup>	0.200
med tree ht	0.204	-0.323 <sup>a</sup>	0.095	-0.167	0.126	-0.088	-----	0.071	0.292	0.208
# 6-10" dbh	0.483 <sup>c</sup>	-0.090	-0.081	-0.399 <sup>b</sup>	-0.208	-----	-0.215	0.268	0.180	0.407 <sup>b</sup>
10-15"	0.057	-0.088	-0.100	-0.364 <sup>b</sup>	-0.048	-----	-0.290	0.258	0.185	0.073
15-20"	0.144	-----	0.016	0.004	0.016	-----	0.121	0.153	0.395 <sup>b</sup>	0.126
20-25"	0.126	0.146	-0.019	-----	-----	-----	-----	-0.121	0.135	-----
25-30"	-----	-----	-----	-0.146	-----	-----	-----	0.291	0.272	-----
large tree ht	0.172	-0.240	0.035	-0.122	0.204	-----	-0.363 <sup>b</sup>	-0.015	0.051	0.149

a - trend at 0.05-0.10

b - significant at p=0.01-0.05

c - significant at p=0.005-0.01

d - significant at p<0.001 (UNCORRECTED p-values)

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**Table A2.8****Spearman rank correlations ( $r_s$ ) of conifer densities (#) and heights (ht) by size classes, with pellet counts on Loomis (n=57)**

seedlings &lt;1"dbh, medium trees 1-5.5"dbh, large trees &gt;5.5"dbh

	<b>ABLA</b>	<b>LAOC</b>	<b>PICO</b>	<b>PIEN</b>	<b>PIPO</b>	<b>PSME</b>
<b># seedlings</b>	0.187	0.053	0.102	0.105	-0.089	0.031
<b>seed ht</b>	0.008	-0.154	0.096	0.173	-0.013	-0.212
<b># med trees</b>	0.136	0.101	0.176	0.130	0.154	-0.170
<b>med tree ht</b>	0.248 <sup>a</sup>	0.115	-0.128	0.042	0.154	-0.167
<b># 6-10" dbh</b>	0.102	0.007	-0.051	-0.294 <sup>b</sup>	0.154	-0.135
<b>10-15"</b>	-0.154	-0.027	-0.105	-0.265 <sup>b</sup>	-0.016	-0.208
<b>15-20"</b>	-0.029	-0.131	0.193	-0.170	-0.016	-0.187
<b>20-25"</b>	-0.187	-0.182	-----	-0.065	-0.016	-0.177
<b>25-30"</b>	-----	-0.382 <sup>c</sup>	-----	-0.127	-0.146	-0.234 <sup>a</sup>
<b>large tree ht</b>	-0.016	-0.089	0.016	-0.072	0.026	0.002

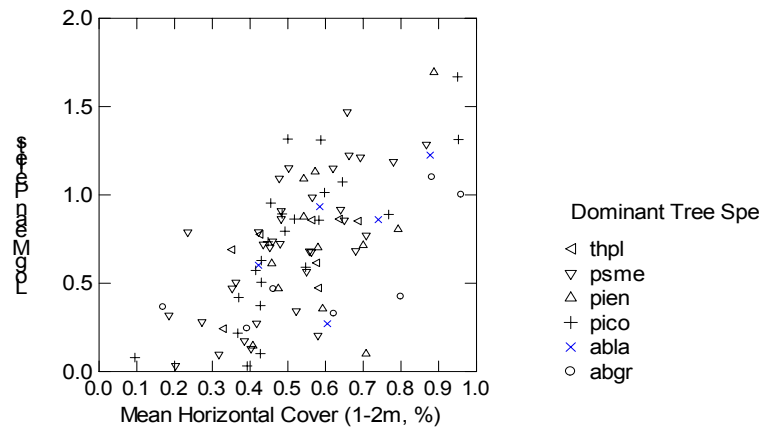
a - trend at 0.05-0.10

b - significant at p=0.01-0.05

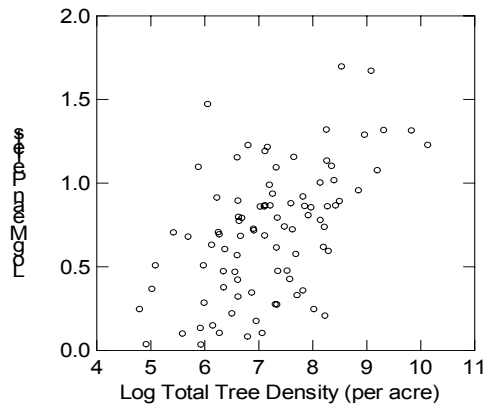
c - significant at p=0.002-0.01 (UNCORRECTED p-values)

**Figure A2.5. Relations of log mean pellets to habitat characteristics**

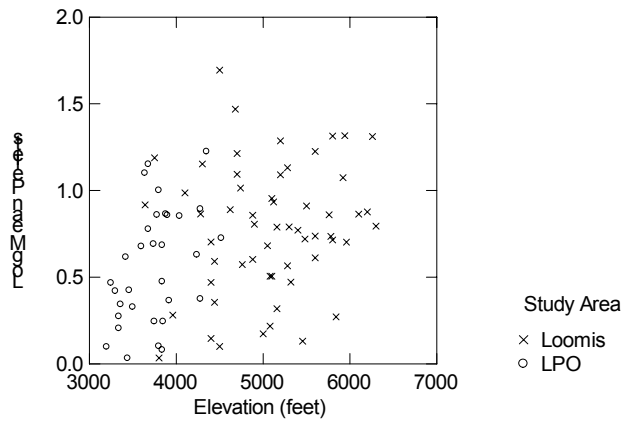
a) horizontal cover (1-2m, %), as categorized by dominant tree species



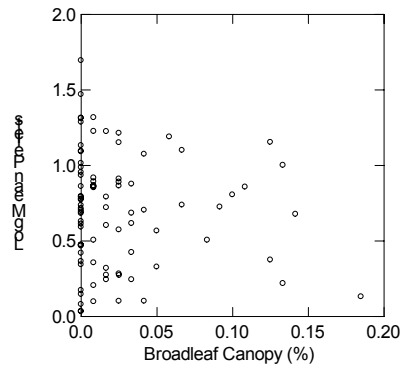
b) trees per acre ( $\geq 1$ " dbh)



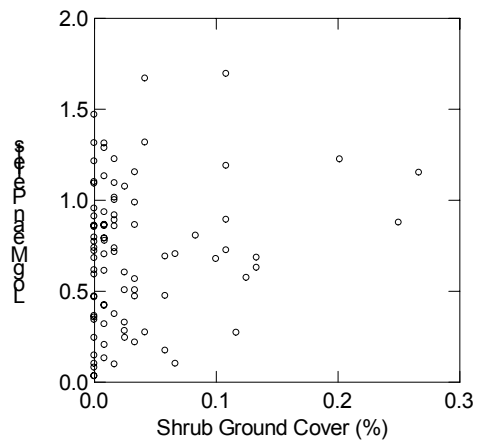
c) elevation (feet), by study area



d) broadleaf canopy cover (%)

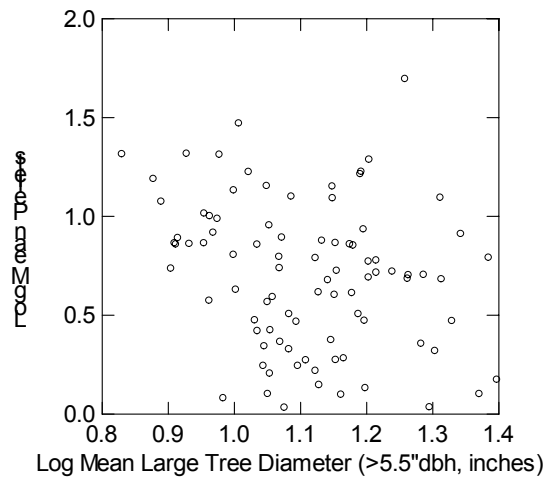


e) shrub ground cover (%)

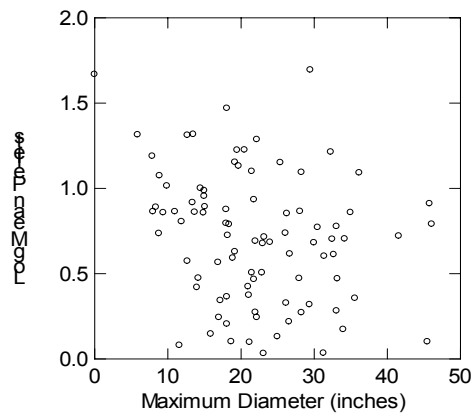


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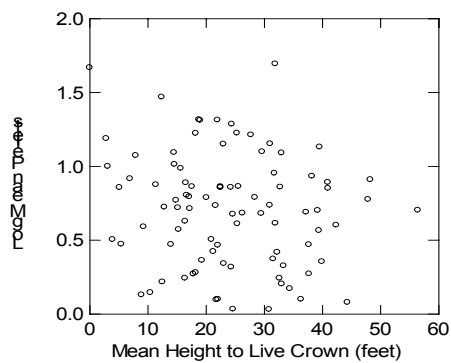
f) log mean large tree diameter (>5.5" dbh)



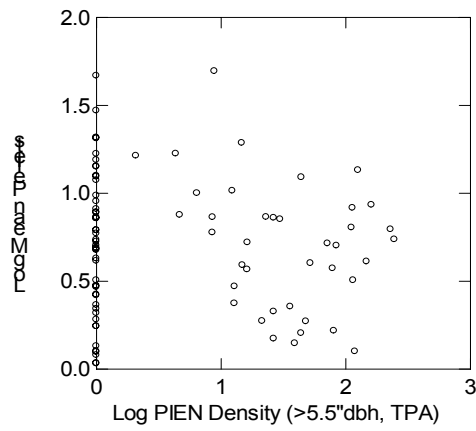
g) maximum large tree diameter (>5.5" dbh)



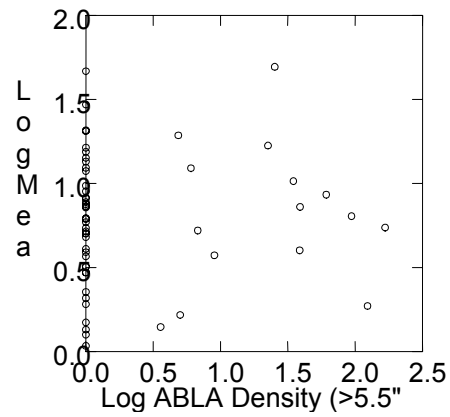
h) live crown (feet) of large trees (>5.5" dbh)



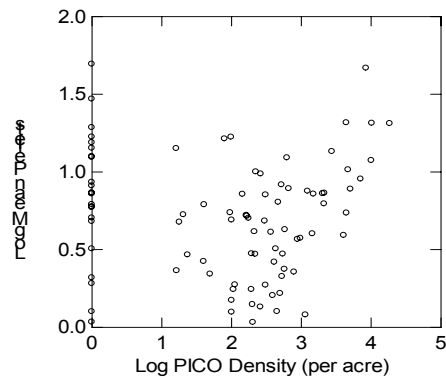
i) log mean Engelmann spruce trees (>5.5" dbh, tpa)



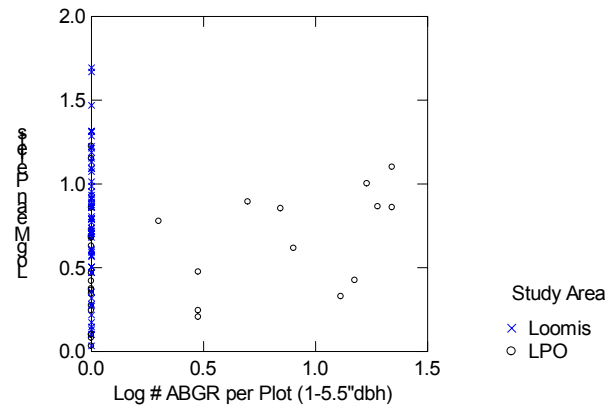
j) log mean subalpine fir trees (>5.5" dbh, tpa)



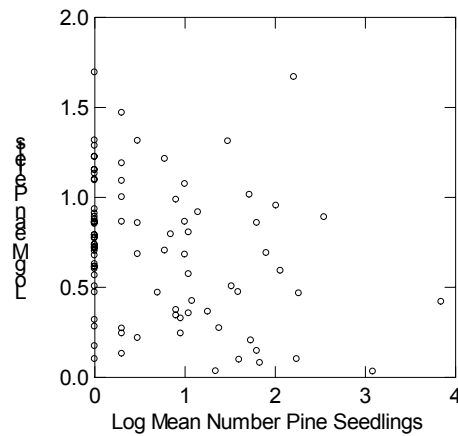
k) log lodgepole pine trees (>1" dbh, tpa)



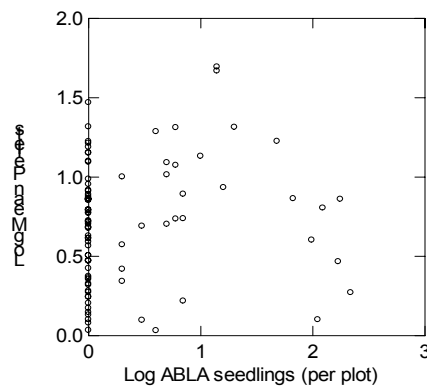
l) log medium grand fir trees (1-5.5" dbh, per plot)



m) log pine seedlings (<1" dbh, per plot)



n) log subalpine fir seedlings (<1" dbh, per plot)



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## 5.4 BROWSE

A list of all species browsed is provided in Table A2.9.

Sites with many pellets had more plots with mean hare browse marks observed than sites with some or few pellets ( $n=90$ ; site  $F_{(1,84)}=6.148$ ,  $p=0.015$ ; category  $F_{(2,84)}=29.203$ ,  $p<0.0005$ ; interaction  $F_{(2,84)}=0.264$ ,  $p=0.769$ ). The consistent presence of browse in plots for each of the three years sampled ( $n=78$ ) differed by pellet category (few<some<many) and was greater in LPO than Loomis (site  $F_{(1,72)}=4.618$ ,  $p=0.035$ ; category  $F_{(2,72)}=22.342$ ,  $p<0.0005$ , interaction  $F_{(2,72)}=0.012$ ,  $p=0.988$ ). Mean observations of browsed shrubs exceeded conifers on LPO (Figure A2.6), where shrubs were more broadly distributed. On Loomis, where shrubs were less distributed, shrubs and conifers were similarly browsed.

**Table A2.9**

**Flora observed with hare browse and frequency of observation summed over years surveyed) by study area, Loomis and LPO.**

Not weighted by amount of browse per species/plant.

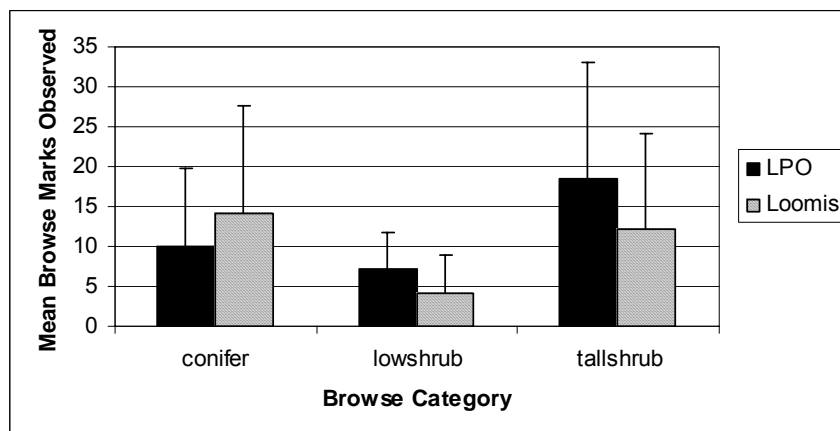
Loomis State Forest			Little Pend Oreille Block		
Species Browsed	Observed Frequency	% Total Observations	Species Browsed	Observed Frequency	% Total Observations
PICO	283	0.16	Rosa spp.	213	0.20
VACCI	255	0.15	VACCI	127	0.12
PSME	222	0.13	THPL	115	0.11
PIEN	131	0.076	PAMY	104	0.098
ABLA	117	0.068	PSME	69	0.065
Ribes spp.	110	0.064	Mahonia spp.	47	0.044
Ledum spp.	90	0.052	Salix spp.	44	0.042
VASC	67	0.039	SPBEL	39	0.037
Salix spp.	60	0.035	PHCA	37	0.035
LAOC	53	0.031	Unknown	28	0.026
Lonicera spp.	51	0.030	CHUM	25	0.024
ALRU	39	0.023	ABGR	24	0.023
SPBEL	38	0.022	PICO	21	0.020
PAMY	35	0.020	PHMA	20	0.019
Lupinus spp.	24	0.014	Alnus spp.	15	0.015
SHCA	23	0.013	VASC	14	0.014
POTR	22	0.013	ALRU	14	0.014
Unknown	18		TSHE	12	
SPCA	14		SHCA	8	
ARUV	13		PIEN	8	
Rubus spp.	9		Lonicera spp.	7	
Rosa	7		LAOC	7	
PIPO	5		ABLA	7	
FRVI	5		HODI	6	
EPAN	5		SYAL	5	
SYAL	4		RUPA	5	
THOC	3		Rubus spp.	5	
RUPA	3		ARUV	5	
CHUM	3		LIBO	4	

**Table A2.9. Continued**

Loomis State Forest			Little Pend Oreille Block		
Species Browsed	Observed Frequency	% Total Observations	Species Browsed	Observed Frequency	% Total Observations
ACER	3		Acer spp.	4	
MEFE	2		PIPO	3	
CARU	2		PIMO	3	
SMRA	1		AMAL	3	
Sambucus spp.	1		SPCA	2	
PHCA	1		Ribes spp.	2	
PERA	1		Lupinus spp.	1	
Juniperus spp.	1		FRVI	1	
COCA	1		EPAN	1	
ASTR	1		COCA	1	
ARTI	1		Cirsium	1	
ARNICA	1				
AMAL	1				

Browsed species were more diverse on LPO than Loomis (Table A2.5), with only three categories (lodgepole pine, huckleberry species, and Douglas-fir) accounting for 40-49 percent of browse observed by season on Loomis. Observed conifer browse differed among all three pellet categories and sites with few pellets had less browse on shrubs than sites with many pellets (Table A2.6). Mean browse observations were correlated with mean pellets ( $r=0.703$ ), conifer browse was correlated with total medium trees ( $r=0.532$ ), and observations of browse on tall shrubs were correlated with shrub ground cover ( $r=0.469$ ).

**Figure A2.6. Mean (SE) browse marks observed by three hare browse categories between study areas (LPO, Loomis).**



**Table A2.10****Scoring browse for Little Pend Oreille Block and Loomis State Forest by season (1999-2001)**

Percent of browse marks weighted by quantity of marks observed: few (x1), some (x3), many (x5)

Little Pend Oreille Block				Loomis State Forest						
Species	Spring		Species	Fall		Species	Spring		Species	Fall
Rosa sp.	14.3%		Rosa sp.	17.7%		Vaccinium	22.3%		PICO	18.3%
Vaccinium	13.2%		Vaccinium	12.0%		PICO	14.6%		Vaccinium	12.1%
THPL	9.7%		PAMY	7.3%		PSME	12.6%		PSME	10.1%
PSME	7.6%		PSME	5.3%		Ribes	7.2%		PIEN	7.3%
PAMY	7.4%		THPL	4.8%		ABLA	6.3%		Ribes	5.7%
oregon grape	4.0%		oregon grape	4.4%		Ledum	4.7%		Ledum	4.3%
phca	3.8%		phca	4.1%		PIEN	4.1%		ABLA	4.1%
Salix	3.3%		Salix	3.7%		LAOC	3.7%		Salix	3.1%
Alnus	3.3%		PICO	2.9%		Salix	3.6%		Lonicera	2.8%

**Table A2.11****ANOVA results for browse observations between study areas and pellet categories (f=few, s=some, m=many).**

Post-hoc test results reported when  $p \leq 0.05$  ( $n=89$ ).

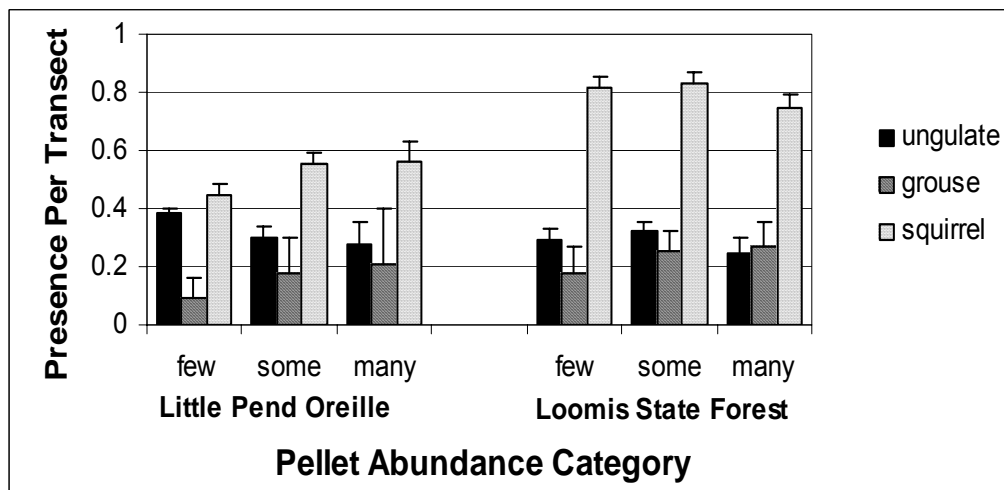
Variable	Study Area			Mean Pellet Category			Interaction of Site and Pellet Category		
	F <sub>(1,83)</sub>	p=	post-hoc	F <sub>(2,83)</sub>	p=	post-hoc	F <sub>(2,83)</sub>	p=	post-hoc
<b>Conifer browse</b>	0.780	0.380	-----	24.960	0.000	f<s<m	1.541	0.220	-----
<b>Low shrub browse</b>	18.072	0.000	LPO>LSF	3.985	0.022	f<m	0.026	0.974	-----
<b>Tall shrub browse</b>	14.053	0.000	LPO>LSF	8.409	0.000	f<s, f<m	1.837	0.166	-----

**5.5 ASSOCIATIONS WITH OTHER LYNX PREY****Red Squirrels**

The mean presence of red squirrels was correlated with snowshoe hare pellets on LPO ( $r=0.404$ ,  $p=0.022$ ,  $n=32$ ; Fig. A2.20) but not Loomis ( $r=-0.183$ ,  $p=0.169$ ,  $n=58$ ). There was a trend for higher squirrel presence on older stands (Loomis higher, site  $F_{(1,86)}=49.700$ ,  $p<0.0005$ ; category,  $F_{(1,86)}=3.521$ ,  $p=0.064$ ; interaction,  $F_{(1,86)}=0.287$ ,  $p=0.593$ ). On Loomis, squirrel presence was significantly correlated with height

( $r=0.637$ ), maximum diameter ( $r=0.557$ ), mean diameter ( $r=0.532$ ), and mean height to live crown of large trees ( $r=0.466$ ), and negatively with density of medium ponderosa pine ( $r=-0.496$ ). On LPO, squirrel presence was correlated with conifer canopy cover ( $r=0.701$ ), large grand fir ( $r=0.664$ ), litter cover ( $r=0.628$ ), and density of medium western red cedar ( $r=0.614$ ), moss cover ( $r=0.601$ ), and density of large cedar ( $r=0.574$ ), and negatively with forb cover ( $r=-0.684$ ).

**Figure A2.7. Mean (SE) presence of ungulate, grouse and squirrel sign by hare pellet category (few, some, many) and between study areas (LPO, Loomis)**



Squirrel presence was correlated with snowshoe hare pellets in spring ( $r=0.369$ ,  $p=0.001$ ,  $n=90$ ) but not fall ( $r=0.122$ ,  $p=0.759$ ,  $n=90$ ). Over the years studied, squirrels were detected at least once in the fall on all transects ( $n=32$  LPO,  $n=58$  Loomis) but not detected in spring on 4 LPO sites and 8 Loomis sites. On Loomis, squirrel sign was present or squirrels were detected on each transect in fall 2000 and nearly every site in 1999 (49 of 50), 2001 (56 of 58), and 2002 (54 of 56). In spring, squirrel sign was less distributed, such that 18 percent of sites in 1999, 6 percent in 2000, and 44 percent in 2001 lacked squirrel sign.

### Grouse

Grouse were detected on all but 9 transects in each study area (23 out of 32 LPO, 49 out of 58 Loomis). The presence of grouse was correlated with snowshoe hare pellets on LPO ( $r=0.389$ ,  $p=0.028$ ,  $n=32$ ; Fig. 20) but not on Loomis ( $r=0.209$ ,  $p=0.116$ ,  $n=58$ ). Grouse sign was more common on Loomis, with a trend for more sign on older stands (site  $F_{(1,86)}=5.263$ ,  $p=0.024$ ; age  $F_{(1,86)}=3.468$ ,  $p=0.066$ ; interaction  $F_{(1,86)}=0.563$ ,  $p=0.455$ ). On Loomis, grouse presence was positively correlated with large lodgepole pine trees ( $r=0.497$ ), canopy cover divided by mean dbh of large trees ( $r=0.593$ ) and negatively with the crown radius of large trees ( $r=-0.446$ ) and mean diameter of large trees ( $r=-0.463$ ). On LPO, grouse presence was correlated with litter ( $r=0.591$ ), density of medium cedar trees ( $r=0.576$ ), and forb cover ( $r=-0.590$ ).

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## Ungulates

Ungulates were detected on all transects of LPO and 56 out of 58 Loomis transects. The presence of ungulates was inversely correlated with the abundance of snowshoe hare pellets on LPO ( $r=-0.420$ ,  $p=0.017$ ,  $n=32$ ) but not Loomis ( $r=-0.146$ ,  $p=0.273$ ,  $n=58$ ; Fig. 20). Ungulate presence did not differ by study area or disturbance history in a multiple ANOVA (site,  $F_{(1,86)}=0.762$ ,  $p=0.385$ ; age,  $F_{(1,86)}=2.9463$ ,  $p=0.090$ ; interaction,  $F_{(1,86)}=0.2169$ ,  $p=0.588$ ). On Loomis, no correlations between ungulate sign and pellets were significant, but the highest ranking correlations were elevation ( $r=-0.305$ ), conifer canopy cover ( $r=-0.303$ ), crown radius of medium trees ( $r=0.387$ ) and total zero scores (0.360). On LPO, deer presence was correlated with large ponderosa pine ( $r=0.700$ ) and forb/grass cover ( $r=0.626$ ).

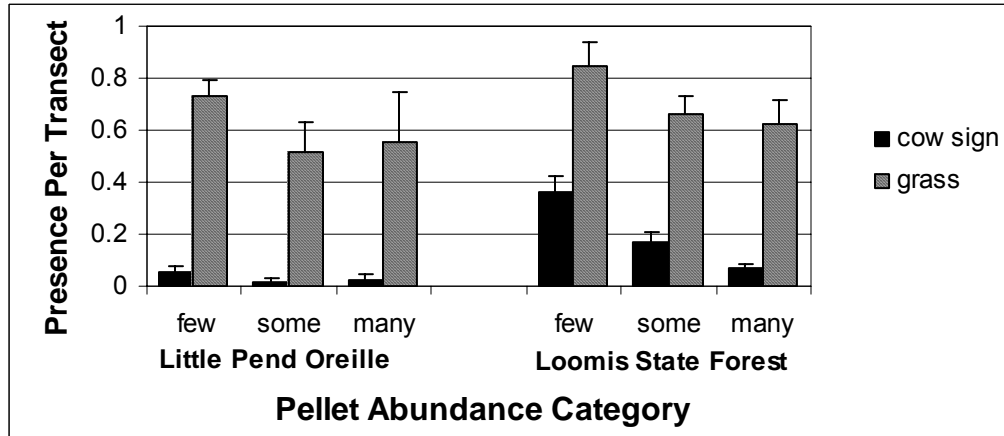
## Cattle

Cows were detected with higher frequency on Loomis (50 of 58) than LPO (8 of 32), Figure A2.8). The presence of cows was negatively correlated with the abundance of snowshoe hare pellets on Loomis ( $r=-0.393$ ,  $p=0.002$ ,  $n=58$ ) and nearly so on LPO ( $r=-0.335$ ,  $p=0.061$ ,  $n=32$ ). Cow presence was greater on Loomis than LPO and there was a trend for more presence in younger stands (site,  $F_{(1,86)}=19.056$ ,  $p<0.0005$ ; age,  $F_{(1,86)}=3.715$ ,  $p=0.057$ ; interaction,  $F_{(1,86)}=2.467$ ,  $p=0.120$ ). On Loomis, cow presence was positively correlated with soil ( $r=0.637$ ) and total zero scores in horizontal cover ( $r=0.493$ ), and negatively correlated with seedling density ( $r=-0.523$ ) and conifer canopy (with conifer ground cover included when canopy was otherwise scored as open,  $r=-0.564$ ). On LPO, cow presence was significantly correlated with Engelmann spruce seedling density ( $r=0.627$ ) and not significant but high ranking: open canopy cover ( $r=0.481$ ), forb cover ( $r=0.461$ ), large tree height deviation ( $r=0.455$ ), and negatively correlated to elevation ( $r=-0.481$ ).

Grass presence negatively correlated with the abundance of snowshoe hare pellets on LPO ( $r=-0.242$ ,  $p=0.068$ ,  $n=32$ ) and nearly so on Loomis ( $r=-0.396$ ,  $p=0.025$ ,  $n=58$ ; Fig. 21). Grass was nearly more frequent on Loomis than LPO, and more frequent on younger than older transects (site  $F_{(1,86)}=3.569$ ,  $p=0.062$ ; age  $F_{(1,86)}=16.264$ ,  $p<0.0005$ ; interaction  $F_{(1,86)}=2.883$ ,  $p=0.093$ ), potentially explaining the co-occurrence of cows with sites that have few pellets (i.e. early regenerating stands) and indicating potential for trampling to occur (seedlings).

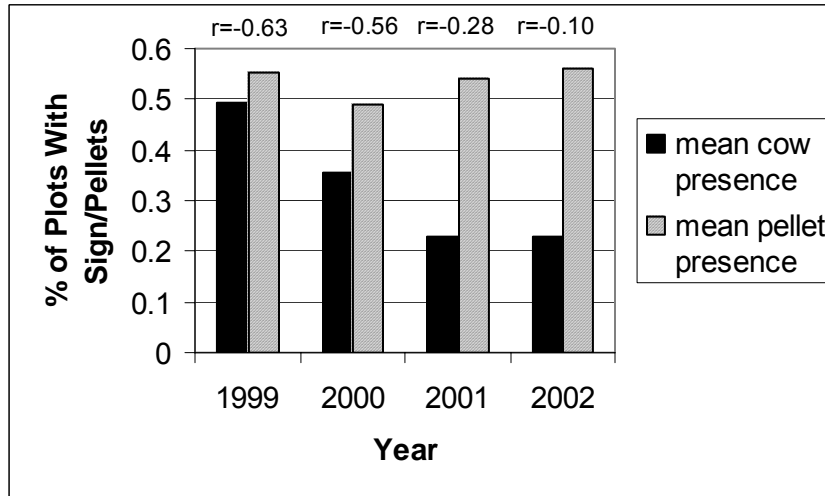
The percent of young stands with high mean cow presence ( $>31$  percent mean cow sign per transect,  $n=15$  of 58) on Loomis was 44 percent (11 out of 25). More of the high cow presence sites were in younger (11 of 15) than older stands, in PSME (11 of 13) rather than PICO types (2 of 8), and had few (8 of 15) or some (5 of 15) pellets. Cow presence was detected for four consecutive years (1999-2002) on 29 percent (17 of 58) of the Loomis transects. Cow presence was highest in 1999 (Fig. 22) and most negatively correlated ( $r=-0.626$ ,  $p=0.007$  uncorrected) to pellet presence. Cow presence was still negatively correlated to pellet presence in 2000 ( $r=-0.559$ ,  $p=0.02$  uncorrected), but not in 2001 or 2002.

**Figure A2.8. Mean presence (SE) of cattle sign observed along pellet transects, by snowshoe hare pellet abundance categories (few, some, many) and between study areas (LPO, Loomis).**



**Figure A2.9. Mean presence (plots/transect) of cattle sign and snowshoe hare pellets observed along 17 pellet transects, by year sampled on Loomis**

The uncorrected correlation between pellet and cow presence is given for each year.



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## 6. Discussion

### 6.1 PATTERNS THROUGH TIME

Between 1998 and 2002, small fluctuations in pellet densities on the study areas (1.5x LPO, 3.3x Loomis) were similar to those expected of southern or montane snowshoe hare populations (Hodges 2000, Murray 2000). Likewise, Koehler (1990a) observed 1.5 fold differences on pellet plots in Washington and Malloy (2000) observed 2.4-4.7 fold differences from 1986-1998 on four individual transects in Montana. Fluctuations in cyclic populations can reach well over 10 hares/ha (25 hare/ac, Keith 1990).

Both the highest and lowest values of hare densities observed on Loomis and LPO are lower than northern hare populations where lynx have been studied, but similar to those reported from other southern areas (Table A2.12). The densities provided here should be viewed with caution because the equations used to extrapolate hare densities from pellet densities were generated from a different study area (Krebs et al. 1987, Krebs et al. 2001). The low year (2000) of pellet densities and presence observed on LPO and Loomis was similarly observed in the Kootenai National Forest, Montana, in a 1998-2001 Yaak hare study (J. Weaver, pers. comm.). The lower hare densities on LPO compared to Loomis were expected, given the historical presence of lynx and casual observations of snowshoe hare signs between areas.

**Table A2.12**

**Hare densities derived from pellet counts within 2 inches x 10 feet “Krebs” plots (Krebs et al. 1987, Krebs et al. 2001).**

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Estimated Hare Densities/ha	Area	Author
High 0.69, low 0.29	Northcentral WA, means from 5 years	This study
High 0.35, low 0.18	Northeastern WA, means from 4 years	
Peak 7.5, low 0.8-1.3	Teslin Plateau, Yukon, means from 8 years	Slough and Mowat 1996
Peak 7-9, low 0.4-1.0	Great Slave Plain, Northwest Territories, means from 5 yrs	Poole 1994
High 0.47, low 0.01	southern BC, means from one year	Apps 2000
0.57 on intensive study plots, 0.14 on extensive study area	Northern Idaho, means from 2 years	Murray et al. 2002

Although pellet presence did not significantly change over time on Loomis, hare pellets were found in 68 percent of habitats in the low as high years on LPO. The correlation of pellets to horizontal cover jumped from 44 percent before the 2000 low to 66 percent during the low, suggesting that hares were surviving in areas of denser cover. Keith (1966) concluded that intrapopulation movements during a hare decline resulted in changes in distribution of hares, such that they occupied 72 percent of habitats occupied during the peak. Fuller and Heisey (1986) observed an increase in presence of pellets in

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all cover types, with an increase in pellets in north-central Minnesota. It may be that occurrence of hares follows a cyclic pattern in LPO. Radio telemetry would be the ideal choice for evaluating potential hare survival and movements associated with density changes. It would also be interesting to see if hare pellets are again found in more habitats in this study as (if) hare populations increase again.

Why wasn't a similar or even stronger pattern of habitat abandonment observed on Loomis, where the change in pellet abundance between years was greater than LPO? With no change in hare pellet presence over the time studied, hares appear to be reliably available in most habitat types on Loomis. The mean total zero scores were much higher on Loomis (18.0) than LPO (12.8), suggesting that cover on Loomis sites was patchier within a stand. Thus, hare response to a low population density may have been to move/survive in denser cover within a stand rather than between stands.

For Washington forest managers, the similarity of pellet numbers among years suggests that habitat relationships can be reliably derived from pellet counts averaged over years sampled. However, habitat relationships derived from only one year's pellet data should be interpreted with caution because there may be some differences in low or high hare years, particularly on LPO.

## **6.2 PATTERNS WITH STAND AGE AND TYPE**

Hare pellets were broadly distributed across age and plant associations on both study areas, with high pellet densities occurring in lodgepole pine, spruce/fir, Douglas-fir, and grand fir types. Although lodgepole pine stands were the most frequently represented in the group of stands with highest pellet counts in this study and pellets were related to high lodgepole pine density, high pellet densities and evidence of successful reproduction (observations of leverets) additionally occurred within mature PSME/CARU, ABLA2/VASC, and PSME/VACA stands. On LPO, the relationship of pellets to plant association was similarly indiscernible in a hare pellet study to the south (Thomas et al. 1998), yet three plant associations common to LPO sites were ranked in the same order (PSME/PHMA > THPL/CLUN > TSHE/CLUN, Table A2.13. For an explanation of the abbreviations see Appendix 4). In other western hare studies, lodgepole pine has clearly been identified as a preferred snowshoe hare habitat type (Koehler et al. 1979, Malloy 2000, McKelvey et al. 2000).

**Table A2.13**

**Comparison of plant association rankings (highest rank listed first) by hare pellet counts between two northeastern Washington studies.**

Associations shared by studies are in bold.

<b>Thomas et al. 1998<sup>*</sup></b>	<b>LPO (this study)<sup>**</sup></b>
THPL/VAME	THPL/ATFI
<b>PSME/PHMA</b>	ABGR/CLUN
ABLA2/CLUN	PIAL/ABLA
<b>THPL/CLUN</b>	ABLA/VASC
TSHE/MEFE	ABGR/LIBO
<b>TSHE/CLUN</b>	<b>PSME/PHMA</b>
ABLA2/TRCA3 and TSHE/GYDR	<b>THPL/CLUN</b>
ABGR/PHMA	<b>TSHE/CLUN</b>
THPL/ARNU3	

<sup>\*</sup>derived from figure 7 in Thomas et al. 1998, an area to the south of LPO;

<sup>\*\*</sup>from DNR inventory plot nearest to transect

The few conclusions of hare pellet relationships to stand age or plant association in this study may also result from the range of studied transects. For example, regenerating forests in the suitable age range for snowshoe hare (20-40 years) were scarce on Loomis. Outside of Loomis, younger sites such as those resulting from a 1970's burn had much higher hare pellet densities than most sites on Loomis (Okanogan National Forest, DNR unpublished data). Hare avoidance of the earliest forest successional stages has been observed across the species' range (Keith 1990, Hodges 2000). In this study, low hare occupancy of earliest successional stages was suggested by the higher forb/grass cover and lower litter, shrub, and moss cover and greater abundance of pine seedlings on sites with fewer pellets. Buskirk et al. (2000) described potential hare habitat characteristics of old forests as including brushy understories, maximum tree diameters, and dense coniferous understories. In this study, there was little evidence for hare preference of gap-phase forests. Older sites on Loomis were likely to have more pellets were likely to have more pellets if they had a closed conifer canopy cover by small diameter trees, particularly lodgepole pine, with relatively low heights to live crown and likely to have fewer pellets if there was a diversity of large trees present (particularly western larch and Englemann spruce), if large trees were tall and had large diameters, as would be expected in gap-phase forests, although snowshoe hare occupancy of older forests was clearly documented. On LPO, older sites were more likely to have higher hare pellet densities if they had closed overstories to the point of much litter accumulation, yet still having horizontal cover and conifer cover, especially regenerating cedar in the form of medium trees and seedlings.

### **6.3 PATTERNS WITH SPECIFIC HABITAT CHARACTERISTICS**

The predominance of horizontal cover as a descriptor of hare habitat that was found in this study has been observed in other areas of the snowshoe hare's range. Cover densities >40 percent within 3-5 feet (1-1.5m) explained 85 percent of winter hare habitat use in northern Utah (Wolfe et al. 1982) and >60 percent cover within 7 feet (1-2m) of the ground were used intensively in Maine (Litvaitis et al. 1985b). In Idaho, Wirsing et al. (2002) found low hare densities in study areas with less than 40 percent horizontal cover.

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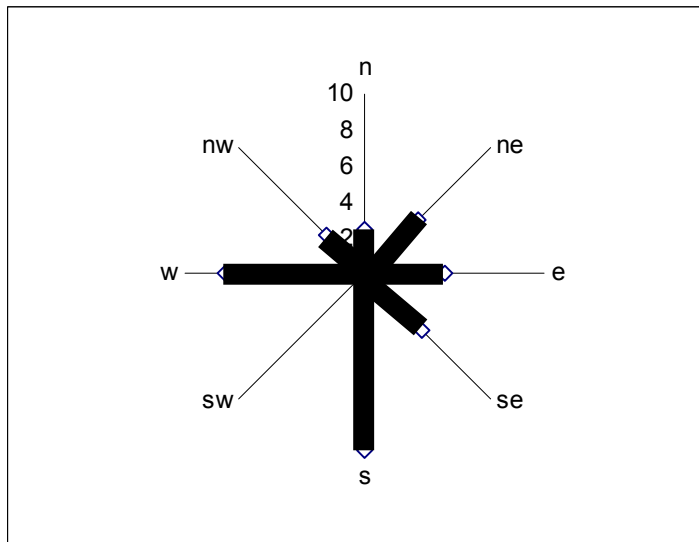
“Refuges” with cover densities of 75 percent (up to 12 feet or 4m tall) were used by hares in winter near Fairbanks, Alaska (Wolff 1980). Cover 3-10 feet (1-3m) above ground in the form of 50-60% conifer foliage cover values was identified as the single most important factor influencing snowshoe hare distribution in New Brunswick (Parker 1986). Likewise, the correlation of shrubs with pellets on LPO was  $r=0.48$  ( $p=0.005$ ,  $n=32$ ), similar to northcentral Minnesota, where Pietz and Tester (1983) found  $r=0.52$  ( $p=0.02$ ,  $n=12$ ) in jack pine/spruce.

The disassociation of older sites with large spruce on the Loomis study area has not been reported elsewhere. Hodges (2000) reported a field survey where forest managers ranked habitats they thought were most likely to contain hares. In Washington and Oregon, lodgepole pine and Douglas-fir ranked highest, but in the intermountain west, spruce/fir and lodgepole ranked highest. Spruce forests are also high ranking in hare use within northeastern states (New York, Rogowitz 1988; Maine, Monthey 1986, Litvaitis et al. 1985b), New Brunswick (Parker 1984), Colorado (Dolbeer and Clark 1975), and northern Utah (Wolfe et al. 1982). Young spruce stands in this study supported high hare pellet densities and Engelmann spruce itself was frequently browsed. Older spruce stands on north-northeastern aspects may have had lower pellet densities than other aspects, suggesting that the microclimate on these sites was perhaps too cold and/or wet to support high hare densities (Figure A2.9).

It is possible that other forest structural characteristics not measured in this study are critical to hares. For example, field observations suggested that perhaps woody debris cover could be important to hares in the absence of dense vegetative cover. However, a preliminary analysis of the relationship between pellet abundance and woody debris cover and cover by specific species of vegetation on a subset of Loomis transects did not reveal any strong associations (Appendix 8). Likewise, large-scale habitat factors such as patch size and amount of disturbed habitat in a given area (Thomas et al. 1998) may influence hare pellet densities. New England cottontails had lower survival where there were larger amounts of disturbed habitat within 0.5km of a habitat patch, large perimeter to edge ratios of habitat patches, and greater amounts of coniferous forest within 1km of a habitat patch (Brown and Litvaitis 1995).

**Figure A2.9. Mean hare pellet densities on older Loomis transects with large Engelmann spruce trees, grouped by aspect (n=22 sites).**

Bar length corresponds to mean pellet densities, scale on northern axis.



Although aspect and topography may influence the distribution of snowshoe hares (Litvaitis et al. 1985b, MacCracken et al. 1988), little evidence for this occurred in this study. The model results indicated that neither slope, aspect, nor slope configuration appeared to be related to hare pellet occurrence. Elevation did correlate with pellets on LPO, indicating that perhaps elevation is more important in some areas (marginal hare/lynx habitat) than others. South of LPO at mean elevations of 1,220 m, Thomas et al. (1998) also found a positive correlation between elevation and hare pellet densities. It is possible that measuring the physical characteristics at each plot rather than at the scale of the site may reveal more relationships.

#### **6.4 PATTERNS WITH ALTERNATIVE PREY**

This study employed a simple methodology to describe the presence of squirrels within sites occupied by snowshoe hares. The large seasonal discrepancy in squirrel detection suggests that future use of the index should be carefully planned to occur during the same season. The results here should be used to aid future study designs.

This study confirms that red squirrels, a principal alternative prey for lynx, occupy older forests. On Loomis, squirrel sign was associated with old forest characteristics that were negatively related to hare pellets (large diameters, crown radii, height to live crowns, large Engelmann spruce and Douglas fir). However, squirrels were broadly distributed throughout sites occupied by hares, including young seral stages and especially in the fall. High occupancy in the fall is presumably driven by dispersing animals. Young lodgepole pine stands may be temporarily attractive to squirrels because lodgepole pine produces cones at an early age (<10 years), dense stands may mean squirrels can travel easily between tree canopies without touching the ground, and cone serotiny may not be expressed for many years (30-60 years, Lotan and Perry 1983). However, dispersing animals in young seral stages may be more vulnerable to lynx than squirrels in older

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stands given that escape habitat is shorter (young trees) and there is less sight distance to detect predators. In British Columbia, red squirrel use of juvenile lodgepole pine forest was comparable to mature forests, varying with cone crop fluctuations (Sullivan and Moses 1986, Ransome and Sullilvan 1997). On LPO, the presence of red squirrel sign was positively correlated with snowshoe hare pellets and conifer canopy. These results contrast with Buskirk et al. (2000), who asserted that red squirrels are absent from sapling-stage forests used by snowshoe hare. Stand thinning, an important concern for decreasing vegetative cover needed for snowshoe hare, has also proven to be detrimental to red squirrel densities (Sullivan et al. 1996) and may therefore also be an important consideration for managers of lynx habitat.

On LPO, pellets and grouse sign were related. On both LPO and Loomis, detection of grouse sign was correlated with habitat features that were also related to pellets. These data indicate that grouse should be available to lynx when lynx are hunting snowshoe hares.

## **6.5 PATTERNS WITH BROWSE USE**

Deciduous woody species are routinely reported as the most common winter food of snowshoe hares, with conifers also used extensively, and herbaceous vegetation important during the summer (Keith 1990). In this study, broadleaf woody species were browsed more frequently where they were more available (LPO vs. Loomis) and sites with many hare pellets were more likely to have browsed shrubs than sites with few hare pellets. Similar to this study, Thomas et al. (1998) also observed that Douglas fir, rose and huckleberry were important browse species in the LPO area. However, two other important browse species in the Thomas et al. (1998) study location, lodgepole pine and serviceberry, were less important in LPO. The list of browsed plants observed in this study (Table A2.9) expands the reported food plant list for the western region as summarized by Hodges (2000). The simple method of browse determination used in this study should be discontinued in favor of a more rigorous design to answer specific further questions.

## **6.6 PATTERNS WITH PRESENCE OF CATTLE SIGN**

This study employed a simple methodology to look for a relationship between cattle presence and hare habitat occupancy. The results discussed here must be considered as exploratory, as information that could be used to develop hypotheses in a future rigorous study design.

The relationships between cattle sign, grass, horizontal cover (zero scores), and open canopies suggest that cattle are largely occupying areas in the earliest stages of succession or in more open forest types than generally preferred by hares. However, the relationship between pellets and cattle sign that changed from negative correlation during years when the most cow sign was observed to no correlation during years of lower cow sign confirms a potential for interaction when cattle densities are relatively high. Likewise, higher animal stocking rates on Loomis compared to LPO led to higher detections of cattle sign and a significant overall negative correlation with pellets on Loomis.

This study could not evaluate changes in hare habitat that may have been caused by cattle that a treatment study (grazed vs. ungrazed) would have been able to detect. For example, McClean and Clark (1980) advised, "Overstocking by lodgepole pine on some

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sites may be reduced by temporarily grazing an area heavily.” The rate of “overstocking” reported, 5,600-6,100 trees /hectare, is within the range preferred by hares (Koehler 1990a). Given the pattern of cattle occurring in the earliest successional stages, it is possible that some sites on Loomis have not reached their naturally stocked potential due to the heavy presence of cattle. Grazing may also retard the growth of lodgepole pine stands compared with ungrazed stands (McClean and Clark 1980). The slow return of some recently harvested sites to hare habitat status could be exacerbated by heavy cattle presence.

## **6.7 CONCLUSION**

This study identified potential habitat variables that can explain approximately 20 percent more variation in pellet densities than our best a priori model. Although the multivariate models give us insight into hare habitat relationships, applying that model towards defining hare habitat on the ground is relatively data intensive. Detailed habitat data is not currently available for DNR-managed lynx habitat. If possible, simplifying the definition of hare forage habitat to something with one or two relatively easy-to-measure variables should facilitate implementation. Section 7 below examines this possibility.

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# **7. Defining Forage Habitat**

What kinds of habitat should be included as Forage Habitat for lynx? Most stands, with the exception of non-lynx habitats, probably have some role as forage habitat for lynx. Lynx can hunt in a variety of habitats from dense young forests to mature forests by using a combination of ambush and sit-and-wait strategies (Murray et al. 1995). Where timber is managed in lynx range, it would be helpful to define a subset of habitats that stand out as important prey areas for lynx. Forage habitats thus defined could be planned for and managed through time. DNR’s 1996 Lynx Plan started with a simple definition of forage habitat as 40 percent cover for 1 meter above mean snow depth. The literature suggested that this was a starting point where hares would use regenerating stands (Wolfe et al. 1982). Literature concerning hare and lynx use of mature stands was equivocal. Therefore, lynx forage habitat was restricted to young stands in the 1996 Lynx Plan (WDNR 1996a). Determining hare use of older stand types on Loomis and LPO was a specific concern for the 1997-2002 effectiveness monitoring effort. The intent of the Lynx Plan was to eventually include all ages and types of forests that typically supported higher densities of hares in the definition of lynx forage habitat.

## **7.1 SETTING A PELLET DENSITY THRESHOLD FOR THE FORAGE HABITAT DEFINITION**

To classify a site as Forage Habitat or not, a pellet density threshold must be set for the Forage Habitat definition. Although we lack lynx hunting data to identify the specific number of hares or pellets that should define habitat, hypotheses state a minimum hare density of 0.5 hares/ha to sustain lynx in northwestern Canada (Ruggiero et al. 2000). The numbers of pellets counted on the 12”x10’ plots in this study are highly correlated to hare densities computed from the 2”x10’ Krebs’ plots imbedded within them ( $r=0.96$ ), such that the minimum hare density suggested for lynx (0.5 hares/ha) is represented by just under 10 pellets per 12”x10’ plot (Figure A2.10). The proportion of transects with  $\geq 9$  mean pellets/plot was 16 out of 58 (27 percent) on Loomis and 4 out of 32 (15 percent) on LPO. Because some stands were specifically included in the sample because of their

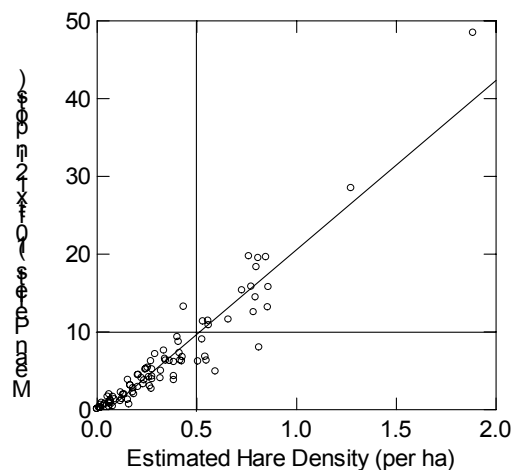
potential to have high pellet densities, the incidence of good pellet sites in the landscape is probably lower. All but two of the 20 transects with  $\geq 9$  mean pellets/plot had hare densities of  $\geq 0.5$  hares/ha on their imbedded Krebs' plots.

## 7.2 APPLYING THE FORAGE HABITAT DEFINITION FROM 1996 LYNX PLAN

As predicted by the literature and identified in the multivariate habitat models, horizontal cover is an important variable for predicting snowshoe hare densities. Specifically, horizontal cover from 3 to 6 feet (1-2 m) was more correlated to mean pellet counts than cover at other height intervals. However, most of the studied transects (86 percent Loomis, 75 percent LPO) had mean horizontal covers of 40 percent or more between 3 and 6 feet (1 – 2 m) from the ground, and therefore would be classified as forage habitat according to the 1996 Lynx (WDNR 1996a) (Figure A2.11).

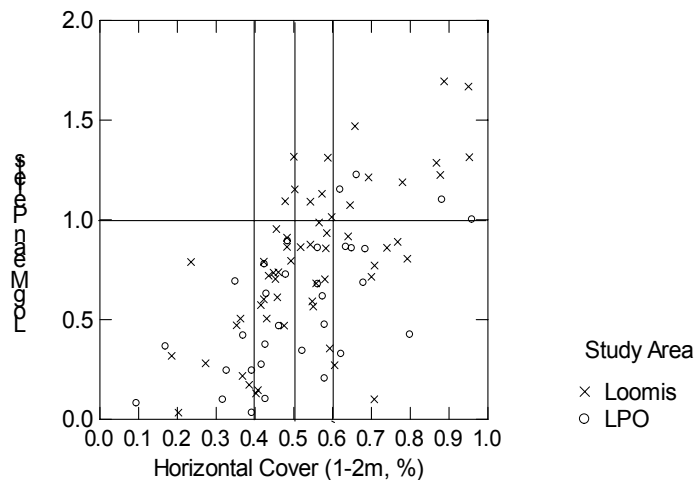
Although all 20 high-pellet sites would be recognized as Forage Habitat if the 1996 Lynx Plan definition is applied (Table A2.14), 74 percent of the sites recognized as Forage Habitat would be sites with lower pellet densities, including 7 out of 16 transects with means of  $<1$  pellet/plot. With a definition of 60 percent horizontal cover, approximately half of the sites recognized as habitat would have high pellet densities, but 35 percent of high-pellet sites would be excluded.

**Figure A2.10. Relation of hare pellet densities in 12"x10' plots to hare densities calculated from imbedded Kreb's plots.**



**Figure A2.11. Relation of log mean hare pellets to mean horizontal cover (LPO, Loomis).**

Note that all but 2 plots with log pellets  $\geq 1.00$  had 0.5 hares per ha or more as calculated from their imbedded 2"x10' Krebs' plots.



**Table A2.14**

**Classification of transects as forage habitat by percent of horizontal cover and number of zero scores.**

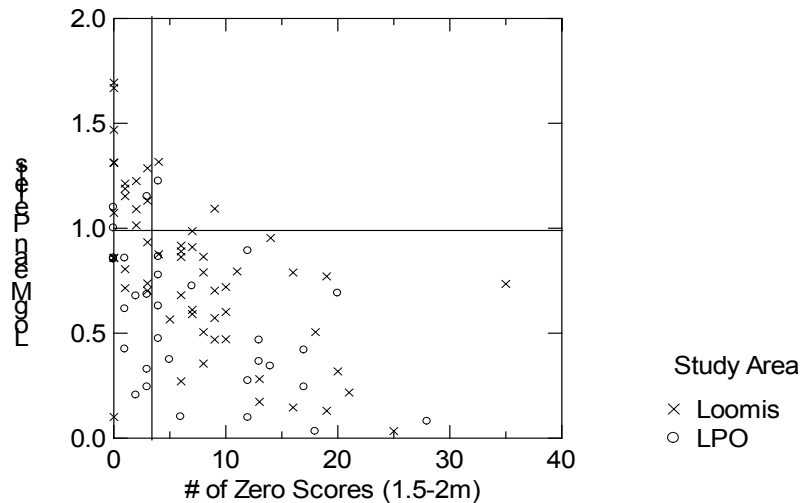
Horizontal Cover	Total number of sites classified as forage habitat	High hare pellet sites		Lower hare pellet sites	
		Classified as high	low	Classified as low	high
40% from 1-2m	76/90	20	0	14	56
50% from 1-2m	49/90	19	1	41	29
60% from 1-2m	26/90	14	6	57	13
<10 zero scores from 0-2m	41/90	19	1	48	22
<4 zero scores from 1.5-2.0m	48/90	18	2	50	20

A middle definition of 50 percent horizontal cover results in the best compromise for misclassification (lacking only one good site), but 41 percent of the 70 low-pellet sites would still be considered forage habitat.

An alternative to the percent horizontal cover Forage Habitat definition is one based on the number of zero scores counted at specific height intervals. Horizontal cover was scored at 50 cm height intervals from ground level to 2.0m. Scores were measured on an ordinal scale ranging from 0 (no cover) to 5, representing 20 percent

cover by each numerical category. Scores of zero reflect the patchiness of available cover (horizontal cover continuity) and are highly related to pellet densities (Fig. A2.12).

**Figure A2.12. Relationship of log mean hare pellets to mean horizontal cover as indicated by zero scores (LPO, Loomis).**



A forage habitat definition based on the number of zero scores counted from 1.5-2.0 m (less than 4 in 40 readings per transect) has the least classification error of the definitions considered in Table A2.14 (22 out of 90 sites). Basing the definition of forage habitat on zero scores might have the added benefit of being more consistent between observers than cover percentages, because it is easier to recognize “zero cover.”

## EXPANDING THE 1996 LYNX PLAN TO INCLUDE MATURE FORESTS AS LYNX FORAGE HABITAT

Results of the pellet study showed that pellet densities were similar between the two age class stratifications (recently disturbed, older) of the studied transects ( $df=90$ ,  $F_{(1,89)}=1.562$ ,  $p=2.15$ ), affirming that it is valid to include old stands as forage habitat. Although stand age did not come out as an important characteristic in the previous chapter’s multivariate analyses of forage habitat, many of the individual model components are related to stand age. For example, mean diameter of large trees, scarcity of pine seedlings, density of large Engelmann spruce, and density of large western hemlock.

The correlation of pellets to horizontal cover (1-2m, %) is substantially lower in older than younger Loomis stands (older  $r=0.22$ , younger  $r=0.90$ ). The discrepancy between age classes suggests that a singular forage habitat definition based on horizontal cover alone will be less accurate for older stands on Loomis. On LPO, there is less difference in the correlation of horizontal cover and pellets between age classes (older  $r=0.73$ , younger  $r=0.58$ ). Breaking down sites by the age of dominant species (vs. sale dates,

which is what the “age class” classification is derived from) reveals the strongest correlations for sites whose primary species are less than 30 years old, but also a steadily high correlation through the available data range (Table A2.15). A similar table cannot be derived for Loomis because the earliest recorded sale date is 1974 and the youngest primary species in the database is 70.

**Table A2.15**

**Correlation of mean pellets per transect to horizontal cover (1-2m) for LPO by age of priority species**

From DNR's FRIS database

Age Priority Species	N=	Pearson R for pellets vs. cover
<20 years	3	0.83
30	6	0.87
40	10	0.63
50	14	0.52
60	20	0.64
70	24	0.69
80	25	0.70
all	32	0.62

**PATTERNS IN MISCLASSIFICATION USING A DEFINITION BASED ON HORIZONTAL COVER**

The previous sections highlighted possible success with a revised horizontal-cover-based Forage Habitat definition but identified mature forests, especially on Loomis, as having a high potential for misclassification. Table A2.16 sorts the classification errors by cover type and stand age for both the 50 percent horizontal cover definition and the >4 zero score definition. Error rates were proportionally higher on LPO using either the 50 percent cover definition (29 percent misclassified on Loomis, 37 percent LPO) or zero score definition (15 percent Loomis, 34 percent LPO), indicating that both Forage Habitat definitions will be more accurate on Loomis. Within Loomis, misclassification was most common in older stands, particularly those dominated by Engelmann spruce or subalpine fir. On LPO, misclassification occurred in both recently disturbed and older stands under both habitat definitions, and no clear pattern emerged with respect to cover type. These patterns of misclassification match what would be predicted from the correlations with horizontal cover.

**Table A2.16 Age and cover type of transect sites in Loomis State Forest and Little Pend Oreille Block**

Numbers in parentheses indicate the number of sites per category that had fewer pellets than indicated by their measured horizontal cover. Numbers with stars (\*) indicate the number of sites per category that had more pellets than indicated by their measured horizontal cover.

Age Classes	LOOMIS STATE FOREST				LITTLE PEND OREILLE BLOCK				
	ABLA	PICO	PIEN	PSME	ABGR	PICO	PSME	THPL	Total
Recently Disturbed Sites									
Available	1	9	2	13	4	4	6	6	45
Misclassified under 50% cover definition	(1)	(1)		(3)	(1)		(3)	(3)	12
Misclassified under <4 zero scores definition					(1)		(2)	(2)	5
Older Sites									
Available	4	7	11	11	3	3	4	2	45
Misclassified under 50% cover definition	(2)	(1)	(8)	1*	(1)		(2)	(2)	16, 1*
Misclassified under <4 zero scores definition	(2)	1*	(5)	1*	(2)		(2), 1*	(1)	12, 3*

Another variable identified in the univariate analysis as potentially important to predicting pellet densities from habitat characteristics on LPO is the presence of large grand fir (Table A2.7). Requiring that LPO Forage Habitat stands have at least 30 large (>5.5 inches) grand fir trees per acre in addition to <4 zero scores reduces error to one missed habitat site and only three sites with less pellets than predicted by cover, all older sites (two grand fir and one red cedar). This definition change reduces classification error on LPO to 12 percent (4 out of 32), and results in a consistent conclusion with Loomis that error is more frequent in older stands.

## CONCLUSION

This study has demonstrated that the definition of forage habitat used in the 1996 Lynx Plan (WDNR 1996) is based upon a sound habitat relationship (horizontal cover at 1-2m above ground). However, the definition is inadequate in at least two ways. First, some types of older stands do contribute hare habitat and therefore should eventually be included as lynx forage habitat. Second, the threshold value of 40 percent cover is too low, allowing too many low-density hare sites to be called Forage Habitat. A new approach that is relatively reliable and simple to identify in the field is desirable.

The analysis in this chapter highlighted the potential for a definition based on horizontal cover scores (zero scores) to have the least error in classifying forage habitat sites (12.5 percent Loomis, 9.5 percent LPO). An additional variable, density of grand fir, is

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necessary to minimize error on LPO. However, DNR is advised to continue testing the forage habitat definition. Especially on LPO, the definition is based on relatively small samples (only four good pellet sites were found). In such small samples, differences between habitat/not-habitat are likely to be artifacts of particular sites rather than large-scale trends. For example, there is no reported biological association between the presence of large grand fir and the occurrence of snowshoe hare. With applying the new forage habitat definitions to both study areas, DNR can anticipate misclassification error in older forests, especially within older Engelmann spruce dominated forests in Loomis, and may wish to directly sample pellets in these stand types to determine forage habitat status rather than, or in addition to, sampling horizontal cover.

The next step for DNR would be to identify new study sites based on the horizontal cover and grand fir predictions and determine whether the expected pellet densities exist. Also, DNR could add new random samples on both study areas to make sure other stand types that may be of use to hares are not missed and then develop new models and definitions for the sites. If new models generated from new data sets employ similar variables, confidence in the model results and subsequent forage habitat definitions will increase.

